MatSeis
User's Manual
version 1.3

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Table of Contents

Overview

This document consists of six sections and three appendices. The six sections discuss the development history of MatSeis, guide the user through installation and setup, and provide a tutorial on MatSeis use. A brief description of each is given below:

- Section 1 provides an introduction to MatSeis, including the development history, and introduces the notation conventions to be used throughout the rest of the document.
- Section 2 outlines the hardware and sofware requirements to run MatSeis and tells how to install the software and how to customize the configuration.
- Section 3 discusses the supported data formats and gives the parameter settings needed for each.
- Section 4 is a detailed but by no means inclusive MatSeis tutorial. The idea is not to teach the user to use every function in MatSeis but rather to provide enough guidance to get started. MatSeis is designed to be intuitive so the user should be able to learn the rest on his/her own.
- Section 5 is an introduction to the four basic data types and how to use the functions associated with them. This is essential information for anyone who wants to put/get data from MatSeis to matlab and for anyone who wants to create their own MatSeis functions.
- Section 6 provides suggestions for what the reader should try next after completing the manual.

The appendices list in detail the functionality of MatSeis. For the experienced MatSeis users, this is probably the most useful part of the documentation as it will include any new functionality. A brief description of each follows:

- Appendix A lists all of the items on each of the menu pulldowns.
- Appendix B lists the items for each of the four types of data popups (origin, wavform, traveltime and arrival).
- Appendix C lists and describes the buttons in the main MatSeis GUI.
- Appendix D lists the environmental variable used to set parameters for a wide variety of MatSeis functionality. Generally these are set in a user's configuration (config) file.

Section 1: *Introduction*

Background

As we began to develop the Automated Data Processing (ADP) portion our CTBT Research and Development Program (CTBTR&D) at Sandia National Laboratories in 1995, a few key needs were identified. First we required access to a wide variety of sophisticated signal processing tools to allow us to quickly develop and prototype promising new algorithms. Second, because most of our data was stored in an Oracle® database, we needed to be able to fetch data from a database and use these tools on it. Third, to make for a user-friendly environment we wanted to meet both of these needs with some sort of Graphical User Interface (GUI). While there are many excellent seismic software packages available which we could have used, we felt that all had significant shortcomings, even allowing for projected modifications. ARS, Geotool, and dbpick were difficult for the user to modify and contain limited signal processing libraries. SAC had a richer library of functionality but supported only basic graphing functions (though this has been improved with SAC2000). Perhaps most importantly, because none of these are commercial packages, the level of support for any of them would always be uncertain. For these reasons, we chose to develop our own software package, now known as ***MatSeis***, which is based on the well-established MATLAB® software package from *The Mathworks*.

Using MATLAB as a basis has many advantages. It is a popular software package, robust, well supported, and available on many hardware platforms. In addition, it is an excellent prototyping environment, with built-in plotting functions and extensive signal processing functionality. Our data viewing needs could also be met easily with MATLAB graphics functions. In short, MATLAB offered a mature, commercial software package with power and flexibility not available in the alternatives.

Development History

We developed MatSeis to meet the fore-mentioned needs. MatSeis is a GUI programmed using MATLAB handle graphics. It provides an interactive time-distance profile display as a platform for data viewing and manipulation. Common GUI controls are provided such as menus, push-buttons, and mouse selections, all written as “m files” in the MATLAB script language and C code interfaced to MATLAB through the cmex API.

The initial MatSeis prototype was completed very quickly by taking advantage of MATLAB functionality.The prototype consisted of Oracle database access routines, a data profile display, and simple plot manipulation controls. Once the power of MatSeis was seen, its functions were expanded and performance improved to make it a more general seismic data visualization, processing, and analysis tool. Start-up configuration and system functions such as printing were also developed. Finally, we improved performance by converting some often-used routines to compiled C MEX-files.

MatSeis' Creators

MatSeis was conceived and created by Mark Harris. The vast majority of the code was written by Mark, though contributions have also been made by Judy Beiriger, Don Funkhouser, John Merchant, Matt Olsen, Julian Trujillo, Mitch Withers, and Chris Young. Many members of the CTBT R&D Team at Sandia Labs have helped refine the organization, look, and feel of the interface. Currently, Chris Young is the caretaker for MatSeis.

Typographic Conventions

This manual uses (or tries to!) the following typographical conventions:

Helvetica	Commands, function names, screen displays, parameter settings within displays.
HELVITICA CAPITALS	System variables.
Italics	Book titles, names of sections in the manual, computer files and directories.
Bold	Key names, module names, menu names, button names, selectable items

When indicating an option of a pulldown menu, we sometimes use the notation: menu->option. If there is a option of a submenu you may see: menu->submenu->suboption.

Some functions are linked with "Accelerator" keys, which means they can be invoked by holding down the "control" key and typing another key. Our notation for this is <ctrl-key>, e.g. <ctrl-f> to use the "f" key to invoke Free Plot.

Selection commands for displayed objects assume that the user has a standard 3-button mouse. "Left-click" means a single click with the left button, "Center-click" means a single click with the center button, etc. "Double-click" means two clicks in rapid succession. If no left/right/center is specified, assume left.

Section 2: System Setup

Platform Requirements

MatSeis was developed on Sun Unix Workstations running the Solaris operating system, but it has since been ported to many other platforms (SunOS, SGI, IBM-RISC, Windows 95, Windows NT). Porting is generally easy, because the vast majority of MatSeis is written as matlab m files, with a small number of routines written in C for improved performance. The only hard requirements for MatSeis are MATLAB® and MATLAB Application Signal Processing Toolbox® (both from *The Mathworks Inc.*), and a C compiler.

Database Requirements

MatSeis works best with a database. A knowledgeable user can enter data in directly, but we do not recommend this. Currently, MatSeis recognizes three database types: CSS Oracle, CSS Flat-files and a generic “local” database format, which is included to help the user design a custom interface to their own database. We hope that the database “requirement” will not ward off interested users; a database can be as simple as a set of ascii tables. We provide an example of a CSS3.0 flatfile database in the data/css area. These files can be used as templates for constructing a database.

Installation

To install MatSeis:

1. Download the file *matseis.tar.Z* from the MatSeis homepage (http://www.ctbt.rnd.doe.gov/ctbt/data/matseis/matseis.html) and put it in the directory intended to contain the MatSeis distribution.
2. Extract the MatSeis distribution:

   ```
   zcat matseis.tar.Z | tar xf -
   ```

   This will create a directory *matseis* which will contain several sub-directories, a few matlab m-files and a makefile. ***Note***: hereafter in this manual we will refer to the matseis directory as MATSEIS_HOME.

3. Several executable versions of MatSeis are included, but if you wish to compile your own, you can compile MatSeis by executing the command

   ```
   make
   ```

   while in the *matseis* directory. This will compile all MatSeis MEX-files using the cmex command. The cmex command is provided with MATLAB® and must be configured to call your native C compiler (refer to MATLAB® documentation).

Configuration

MatSeis can be configured to start up with a custom configuration (e.g. data set, set of travel time curves, etc.). This is done by setting environment variables (see Appendix D) either by hand or in a start-up script (discussed later) or by using a configuration file. When MatSeis starts it first uses default settings, then reads all environment variables from the startup script (if they are set), and finally reads variables from a configuration file (if one is specified in the startup script). To avoid confusion, it is important to keep this order of precedence in mind.

The file *run_matseis* in the *template* sub-directory is a start-up script which can be used as a starting point. The file may be copied to a user's home area and edited as needed. Be sure to set the variables MATSEIS_HOME and ORACLE_HOME appropriately for your system. To use the configuration file option, set the environment variable MATSEIS_CONFIG_FILE to point to a configuration file of your choice. An example of a configuration file is *config* in the *template* sub-directory. The configuration file may be changed while MatSeis is running by using the **Reconfigure** option of the **File** pulldown (see Appendix A), which can be useful if the user is switching between different data sets and/or databases. In fact, for quickest setup, we recommend storing config files with each data set.

The functionality available within MatSeis can be customized with the *ms_start.m* file. An example can be found in the *template* sub-directory. If this file is in the MatSeis search path it will automatically be executed. Each user can define their own custom start-up features (i.e. extra menus, color scheme) using this file. For example, you can include your own matlab directory in the MatSeis search path, by setting the MATLABPATH environment variable accordingly.

Section 3: Data Formats

MatSeis was originally developed to interact with an Oracle® CSS3.0 database, but to make the software more generally useful we have expanded the range of acceptable data formats. The following data formats are currently supported:

Type	Description
Oracle® CSS3.0	CSS 3.0 accessed by SQL
Flatfile CSS3.0	CSS 3.0 flatfile (ASCII) database
Local	generic template

All data access routines are located in the *database* directory. E.g. r#_tablename.m is the routine that reads the specified table for the given # data format type (1=Local, 2=CSS Oracle®, 3=CSS Flatfile). Some write routines are provided (w#_tablename), but this capability has not yet been fully developed or tested, so the user should take care when utilizing these.

Below we discuss each of the formats briefly.

1. Local
   For those who have other types of database formats, we have provided a generic local format which can be modified as needed. A set of templates for the example local data format are in the directory *data/local*. The files used are:

network:	list of networks
origins:	list of origin information
stations:	list of station information
channels:	list of channel information
data:	list of data information

   An example of raw waveform data is the file *1995260/BB_be.w.*

   To use the “Local” data format, the user must set the environmental variables:

MATSEIS_DATABASE_TYPE	to “LOCAL”
MATSEIS_LOCAL	to the top level directory for the local database

2. Oracle® CSS
   For this format, the information is accessed from the database using sqlplus commands. The database tables currently accessed are:

   assoc, arrival, event,instrument, lastid, network, origin, origerr, sensor, site, sitechan, stamag, wfdisc, wftag

   To use the CSS Oracle® database format, the user must set the environment variables:

MATSEIS_DATABASE_TYPE	to "CSS_ORACLE"
MATSEIS_ORACLE_HOME	to oracle home directory
MATSEIS_SQLPLUS	to the sqlplus command pathname
MATSEIS_DATABASE	to the database name
MATSEIS_PASSWORD	to the database password.

Further, we recommend that whenver setting up MatSeis to access an oracle database that the user first verify that their Oracle environmental variables are setup properly by trying a simple database query command such as will be formed by MatSeis: e.g. sqlplus username/password@database_name. If this command does not get you into the database where you can begin querying, do not bother to try to use MatSeis to access your database: it will not work. See your database administrator for help before proceeding.

3. Flatfile CSS
   The database tables accessed are the same as those used for Oracle database interactions, but in this case the data comes from flatfiles. Note that the information must be in the specified columns (see the CSS3.0 schema), and that each line must be the correct length for each table. Failure to verify these is probably the most common trouble encountered when using flat files. Probably the best way to track down problems is to compare your files with a set that works (see the demo "database" in matseis/data/css)

   For a CSS flatfile database, the user must set the environment variables:

MATSEIS_DATABASE_TYPE	to "CSS_FLATFILE"
MATSEIS_FLAT_FILE	to the top level directory for the flatfile database

   Again, this is generally done in the start-up or config file.

Note that the user can actually switch between database types while in a MatSeis session manually by using the **Input Database Setup** option of the **File** pulldown (see Appendix A), or by reconfiguring.

Section 4: Tutorial

Goals

The objective of this tutorial is to get the user started by teaching the *basics* of reading, writing, viewing, and processing data using MatSeis. Once these skills have been learned, the user should be able to learn most of the rest on his/her own. Thus, we do not attempt to describe the use of every option of every menu in MatSeis. While that would be a worthy goal, it is beyond the resources currently available to us.

Starting MatSeis

MatSeis is a MATLAB application, so MATLAB must be running for MatSeis to run. The simplest way to start MatSeis is to `cd` to the *matseis* directory and type the command `matlab`. MATLAB will find the *startup.m* file in this directory and execute it, which runs *matseis.m* which starts MatSeis.

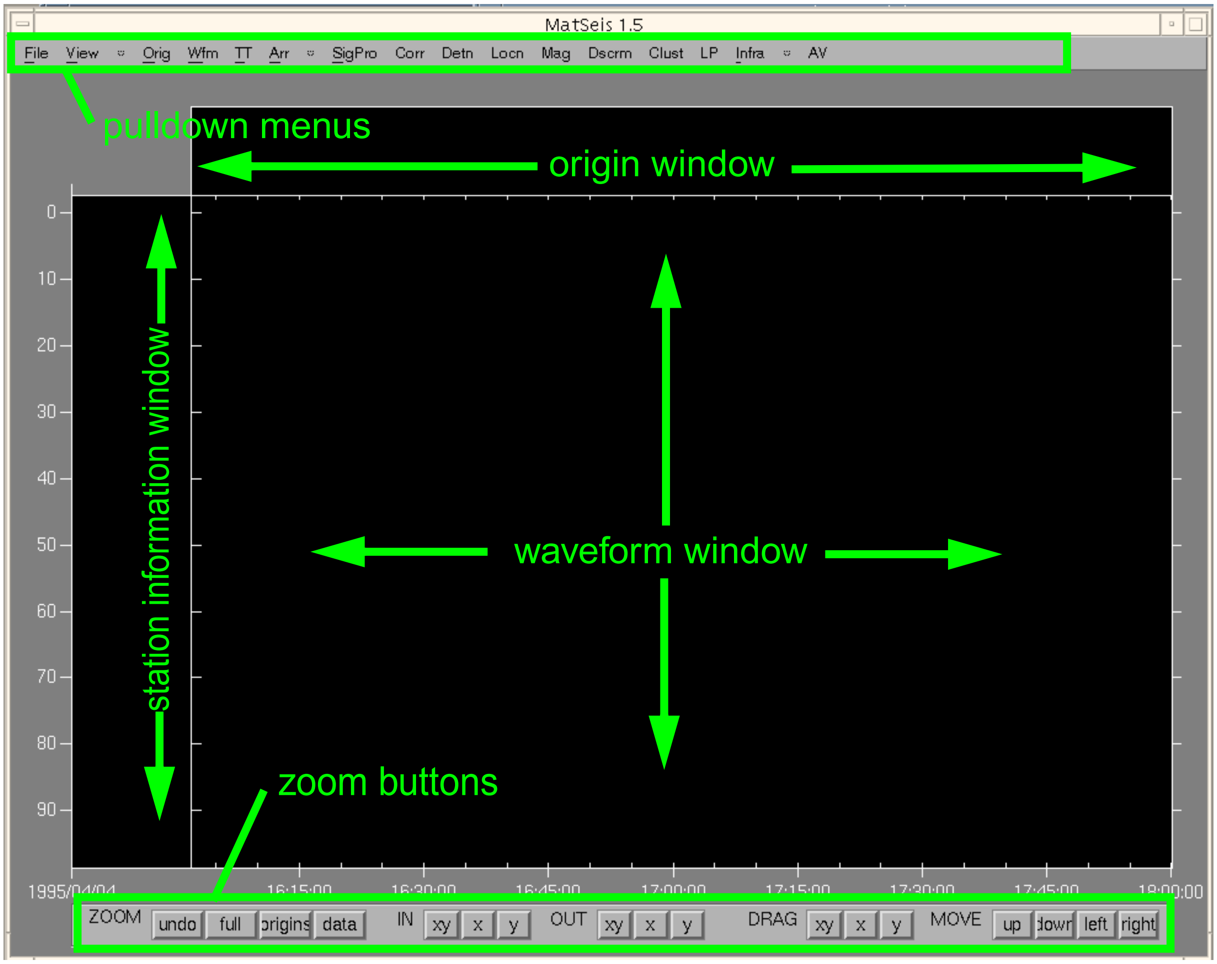
This, however, is not the startup method we prefer. We recommend the use of a startup script file, like the example *run_matseis* include in the template directory. This file sets the `MATLAB_PATH` environmental variable to include the *matseis* directory and any others the user wants, sets the environmental variable `MS_CONFIG` to point to a particular configuration file (more on this later), and then starts up MATLAB. Please examine this file to see how this is done. Due to the addition of the *matseis* directory to the MATLAB search path, MATLAB will find and run *startup.m* (examine this file too) which will in turn run *matseis.m* which will launch MatSeis. Note that with this method the user does not actually have to be running MATLAB from within the MatSeis directory which is an advantage should the user want to write out any files.

We recommend that users copy *run_matseis* to their home area and modify it as they like. The user can easily add their own matlab paths after or before the MatSeis paths, can decide which version of MatSeis they want to point to if there are more than one installed on there system, can point to the config file of their choice, and can choose which version of MATLAB to run if more than one is available.

If MatSeis crashes or is exited, you may restart it by typing `matseis` at the MATLAB command prompt, though depending on the severity of the crash it may be better to exit MATLAB entirely and re-run the *run_matseis* script. This is generally what we do.

Basic Display Layout

After starting MatSeis, the MatSeis display window will appear on the screen. This window can be thought of as being composed of five areas: (1) the Waveform Window, (2) the Station/Channel Information Window, (3) the Origin Window, (4) the Pulldown Menus, and (5) the Zoom Buttons.



The Waveform Window, where the waveforms are plotted, is in the center of the display. Time is along the x-axis and distance (in epicentral degrees) is along the y-axis. To the left of the Waveform Window is the Station/Channel Information Window which displays station and channel information for waveforms displayed. At the top of the Waveform Window is the Origin Window which shows information for any origins (i.e. events) read in. At the bottom of the display are the Zoom Buttons which consist of numerous buttons used for shifting the viewing reference frame (e.g. zooming and translations). Across the top of the display are the Pulldown Menus which consist of several pulldown menus (hereafter "*pulldowns*") grouped by use. The leftmost group of pulldowns **(File, View**) are used to control the database interaction, manipulate and print the graphics window, launch a few critical tools (map, free plot, measure tool) and to exit MatSeis. The next group of pulldowns (**Orig, Wfm, TT, Arr**) are used for performing various actions on the four defined types of data. The rightmost pulldowns (**SigPro, Corr, Detn, Locn, Mag, Dscrm, Clust, LP, Infra**) are used to process and analyze the waveform data. The final pulldown (**AV**) is used to send MatSeis objects to ArcView (this of course only works if the user has Arc-

View available).

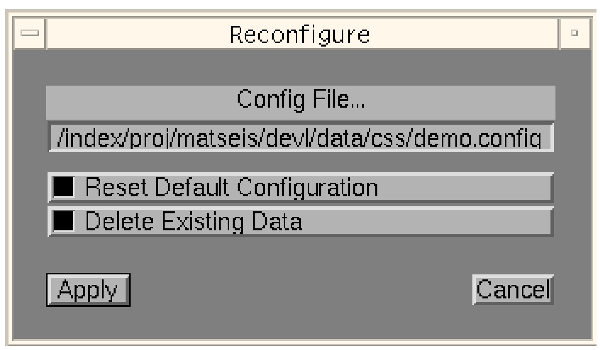
Working with Data

For the tutorial we will use data from 4 stations of the IRIS broadband global network for the January 17, 1994 Northridge (California) event which is included in the standard MatSeis release. The data is in CSS 3.0 Flatfile format and can be found in MATSEIS_HOME*/data/css.* Please refer to the files in this directory as you work through the tutorial. These files can be used as templates for reformatting the user's data files. Note that we include a config file for this data set in the directory.

Reconfiguring

We strongly recommend the use of config files to save the user the trouble of having to type in lots of information to set various parameters. To illustrate their use, we will reconfigure using the config file provided with the demo data set. Note that this config file could have been pointed to using the MS_CONFIG environmental variable in the user's run_matseis script in which case MatSeis would have come up already configured, with data and travel time curves already read in.

To reconfigure, select the **Reconfigure** option of the **File** pulldown menu. You will get a popup like this:



Click on ***Config File*** and use the resulting popup to set the config file to the demo.config file found in MATSEIS_HOME/data/css. The **Config File** window within the reconfigure popup should now show the full path to the demo.config file. The **Reset Default Configuration** button determines whether or not to use this file as the default configuration file for the MatSeis session. Go ahead and select this if it is not already. The **Delete Existing Data** button will delete any data already read into MatSeis before reconfiguring. In this case it does not matter whether this button is pushed or not because we have no data in MatSeis yet, but for a case where you had read in one set of data and wanted to add in another set of data (say another event) without wiping out the first set, you would not want this button set. Once you have made your selections, click on the **Apply** button to reconfigure. In this case, the config file specifies that MatSeis read in an origin (#1), 4 waveforms (PASBHZ, NNABHZ, KIVBHZ, and LBTBBHZ), their associated arrivals, and P and S travel time curves. To see how this was specified, view the *demo.config* file and refer to Appendix D for descriptions of all of the environmental variables which can be set in config files.

Sadly, for the tutorial, we want to teach you how to read data in manually so we will now delete all of the data that we have just read in! First the origin. Use the **Delete** option of the **Orig** pulldown and select origin #1 (the only choice in this case). You should get prompted with a popup GUI to ask if you want to delete the associated arrivals too. Choose **Yes**. Both the origin and the arrivals should now be gone. All that remains is to delete the waveforms. Use the **Delete->All** option of the **Wfm** pulldown. You should now have a fairly blank looking MatSeis display, and are ready to begin to learn how to read in data manually, but remember how much easier it was with the config file!

Database Setup

Data can be read in using the pulldown menus, but first you must set the database parameters properly if they are not already. Check the database configuration using the **File** pulldown. Choose the **Input Database Setup** option. A window will pop-up offering choices of types of database. Select as appropriate for your system (CSS 3.0 Flatfile for the tutorial) and click the **Apply** button. A new popup will appear:

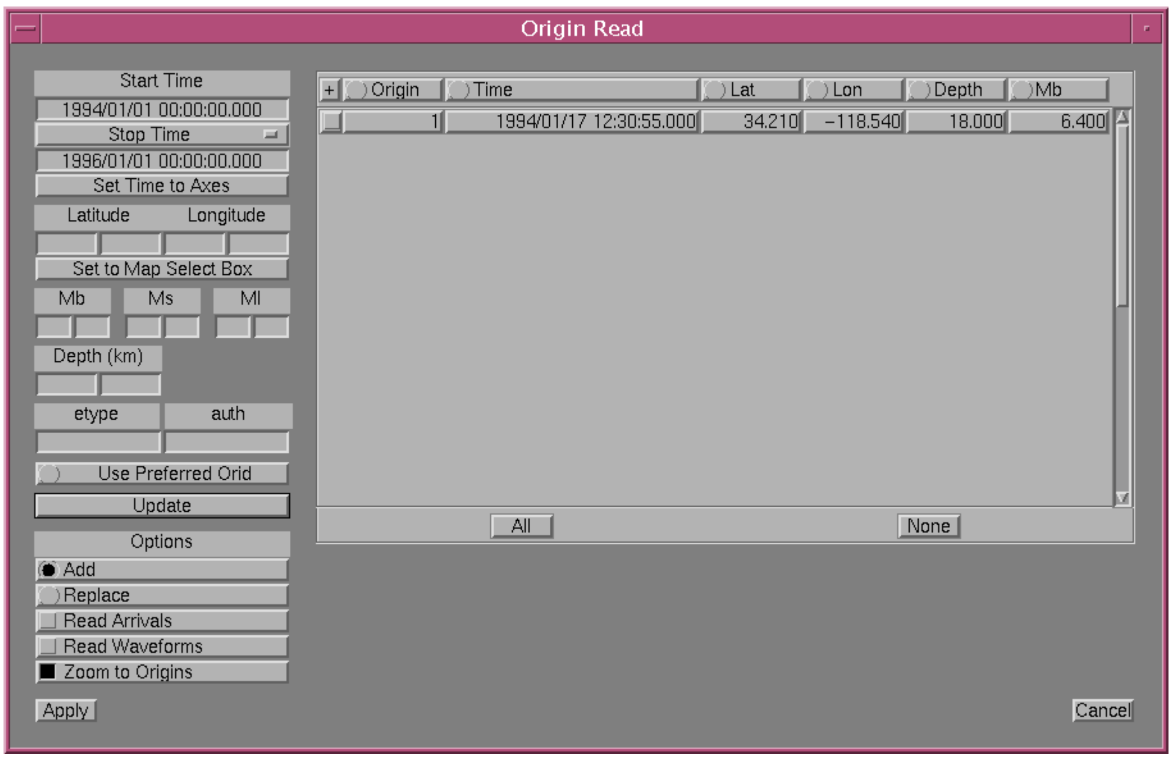
Because we reconfigured with the config file for the tutorial data set, all of the parameters should already be set correctly. For the purposes of the tutorial we will discuss them anyway. For the flat-file option (as shown above), the user must specify the directory where the database files reside (MATSEIS_HOME*/data/css*). For flatfile, you must also specify the prefix for the files/tables (if applicable) and the names of the tables/files (if different from the default names). For example, the default *origin* and *arrival* table names are origin and arrival without prefixes. If your files are named *myfile.origin* and *myfile.arrival* then you must set **prefix** = myfile, **origin file name** = origin, and **arrival file name** = arrival. For the tutorial the prefix is demo and the table names are the default names so no changes should need to be made.

Select Apply when you are finished and your database should be setup. If you have difficulty subsequently reading data, you should carefully step through your database setup again and verify that all of the information is correct.

Note that if you had selected as your input database type CSS 3.0 SQL (i.e. an Oracle database) you would have had to enter some additional parameters (**username**, **password**, **database name**, **sqlplus command**). Once the database parameters have been set, however, the way you would use MatSeis would be much the same.

Reading Origins

Select the **Read** option from the **Orig** pulldown and the Origin Read Window will appear.



This display works in two ways. First you read origins from the database to set up a list of origins to choose from, then you select which of these origins will be read into MatSeis. To set up the list, enter the various search constraint parameters to the left (e.g. **Start Time**, **End Time**, **Latitude, Longitude**, etc.) and left-click the **Update** button. For a flat file database like the demo data set, only the time parameters are used. Bracket the time interval by typing in **Start Time** and **End Time** (or alternately, **Duration**). For the tutorial pick any times which will bracket the Jan. 17, 1994. E.g try 1994 through 1996. Note that if the month, day, and/or time are omitted they will automatically be set to the minimum values. You can also set the **Start Time** and **End Time** to the time interval defined in the waveform window by selecting the **Set Time to Axes** button. If you are using an Oracle database, you can further refine the query by specifying acceptable values for the **Latitude**, **Longitude**, **Mb**, **Ms**, **Ml**, **Depth**, **etype**, and **auth**. The range in **Latitude** and **Lon-**

gitude can be set to the region defined in the **Map Tool** by selecting the **Set to Map Select Box** button (see **Map Tool** tutorial). Once you have the parameters set, left-click on the **Update** button to query the database for all origins in the database in this range.

All of the origins in the range should now show up in a list to the right (see the figure above for an example). In our case, there should only be one (the 1/17/1994 Northridge event). If no origins are displayed there is probably something wrong with the **Directory** value in your database setup. To be safe, make sure to use the absolute path name *(e.g. /index/devl/ctbt/matseis)*.

Once the origins are read from the database, they can be selected for display in MatSeis. You can **Select All** or select individual origins by clicking the buttons next to the orids (origin ID numbers). Several sorting options are available to aid in finding origins of interest. Selecting the button at the top of each column (Orid, Time, Lat, Lon, Depth, Mag) will sort by that field; selecting the **+/-** button will reverse the order of the sort. For the tutorial, select the single origin shown and proceed.

Once the origins have been selected you can specify further options. **Add** or **Replace** determine whether the selected origins will be added to any already in MatSeis or will replace them. In this case there are no pre-existing origins so either can be chosen. **Read Arrivals** will cause any arrivals associated with the selected origins to be read as well. For the tutorial do not select this as we want to show how to read arrivals separately. **Zoom to Origins** will zoom the time interval of the display to bracket all of the selected origins (in this case just one). Select this option.

When all origins to be displayed are selected and the options are set, select **Apply**. The orids (unique ID numbers) for the selected origins should now be visible in the **Origin Window** of MatSeis.

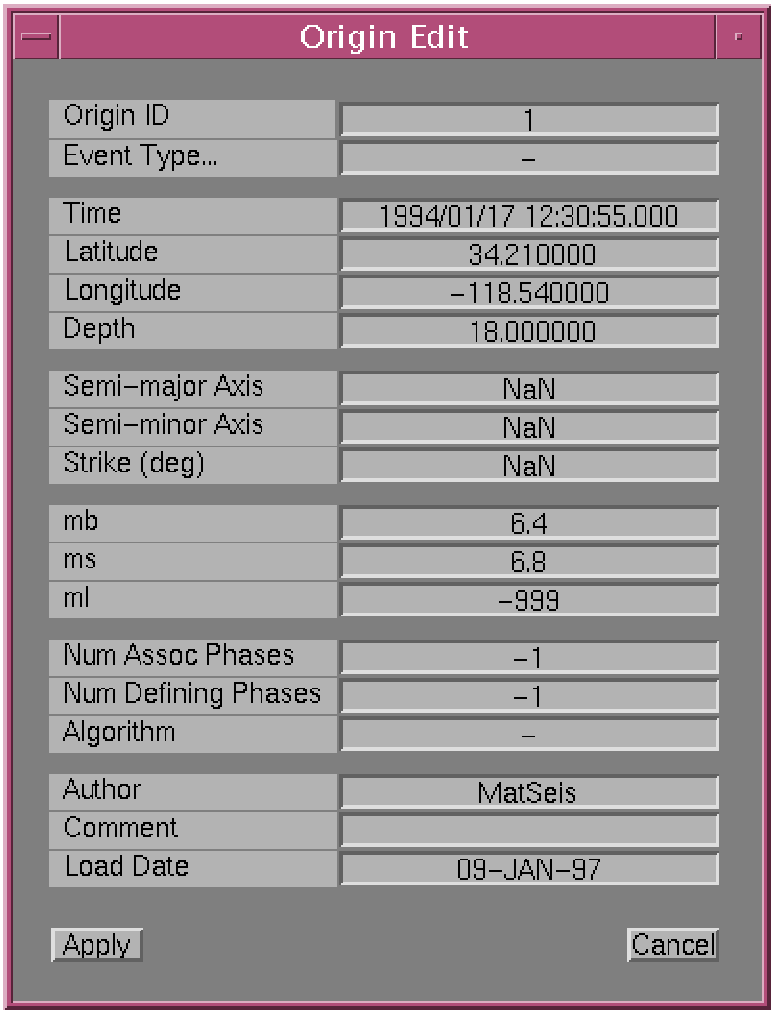
Note that there is nothing (other than common sense!) to prevent one from reading the same origin into MatSeis over and over again. There is currently no logic to check and see if the origin already exists so MatSeis will simply add it again and again if you chose **Add** instead of **Replace**. Thus unless you are *certain* that you want to add origins to those already in MatSeis, we recommend using **Replace**.

Origin Functions and Properties

Origins are selectable objects with a variety of applicable functions and with properties which can be displayed and edited. The full set of origin functions is accessed through the **Orig** pull-down (Appendix A), but a limited set can be accessed directly by left-clicking on the orid in the Origin Window to invoke the Origin Functions Pop-up (see Appendix B).

Select will select the origin, **Edit** will access origin properties via another pop-up (described below), **Raise** will move it in front of other orids (if they overlap), **Lower** will move it behind, **Erase** will hide the origin from view but not from memory, **Delete** will remove the origin from view and from MatSeis, and **Cancel** will dismiss the pop-up.

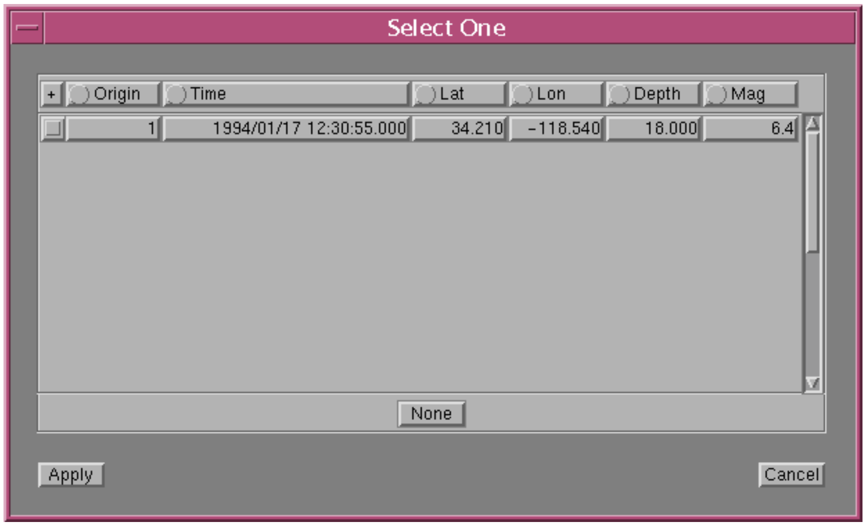
First choose **Select** to select this origin, and then Choose **Edit** to bring up the Origin Edit Window.



This window can be used to review or edit any of the origin properties (e.g. if you wanted to add a comment). All of the fields are editable. Select **Apply** after changes have been made to save them or **Cancel** if no changes are desired. For the tutorial we have no changes so cancel out of both the Origin Edit Window and the Origin Functions Pop-up. Before you proceed to the next section make sure that orid 1 (the Northridge event) is selected. Note: only one origin can be selected at a time.

If you are working with a large number of origins it may be difficult to find the origin you want in the Origin Window. In this case, it is easier to select an origin using the **Select** option of the **Orig** pulldown. This will bring up a selectable list of all the origins currently in memory, e.g.

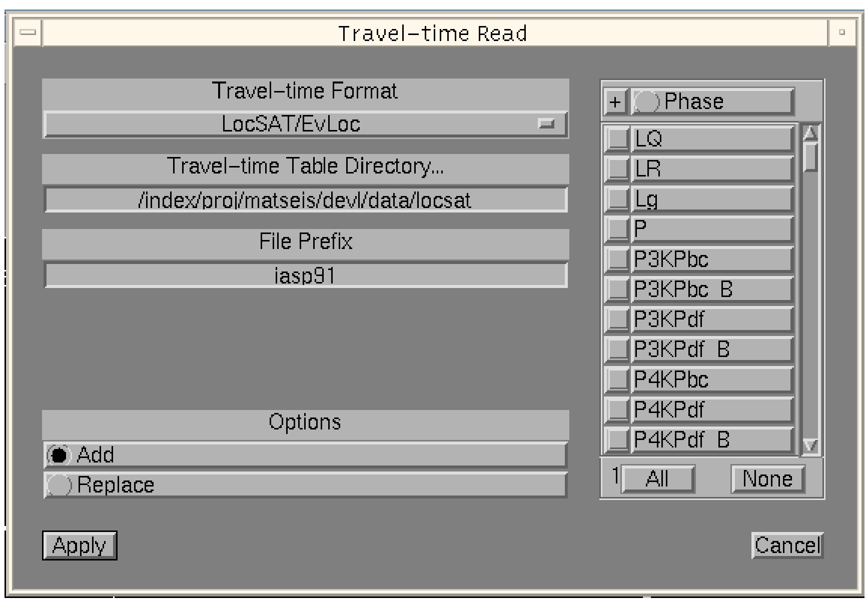
.



Choose the one you want and then choose **Apply** to select it in the MatSeis Origin Window. Note that as with the Origin Read Window, the information here can also be sorted by any of the columns. For the tutorial, go ahead and select the origin 1, the only one in the list.

Reading Travel-time Curves

We want to read waveform data, but first we will show how to read travel-time data because the travel-time curves are very useful for setting the time interval for reading waveforms. Select the **Read** option from the **TT** pulldown and the Travel-time Read Window will appear.



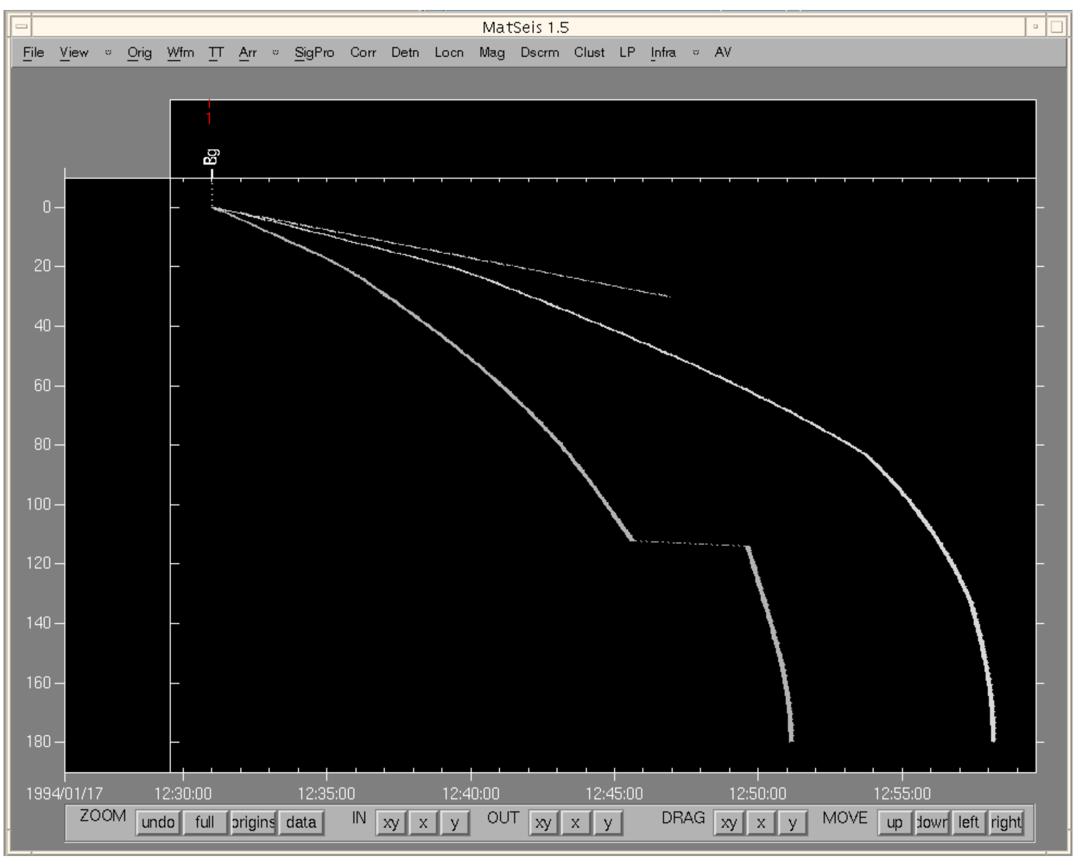
Select **Travel-time Format** to pop-up a list of the supported formats (LocSAT/EvLoc, ASCII Matrix, Master Image). Examples of each format can be found in the MATSEIS_HOME*/trav-time* directory (*locsat*, *ttmat*, *mimage*). For the tutorial we will use LocSAT/EvLoc because a large set of IASP91 tables in the LocSAT format are included in the standard MatSeis release. For most users who want to set up their own tables, however, ASCII Matrix is probably the most useful (and intuitive). Next specify the **Travel-Time Directory** where the travel-time tables can be found (MATSEIS_HOME*/data/iasp91*) and the **File Prefix** of the travel time tables (*iasp91*).

If all of the above are valid, a list of **Phases** should now appear to the right which will include an entry for every table in the specified **Travel-time Table Directory**. If it does not, check the settings again carefully. Make sure that the paths and prefixes correspond to actual locations and files. To select curves to read into MatSeis, use **Select All** or select phases individually. For the tutorial select P, S, and Lg. Select **Add** to add the travel-times to any already in memory or **Replace** to clear. In this case, choose **Replace** in case any travel time curves have already been set up in MatSeis so we do not get duplicates. Select **Apply** and the travel-time curves will be read and displayed. If you find picking a few phases from the large list cumbersome (we do!) we recommend setting the travtime phases in the config file so that they are automatically loaded on startup or reconfigure.

Displaying Travel-time Curves

If the Northridge origin is selected, the travel time curves (shown in the Waveform Window) should be tied to that origin. The curves may be difficult to see because of the time scale and/or their color. To change the color of the travel-time curves use the **Color** option from the **TT** pull-down. Choose **random** to get different colors for each curve. To get a better view of the selected origin, left-click the **full** button in the Zoom Buttons area. This will zoom the waveform window to bracket the travel-time curves that are currently shown.

The display should now look something like this.



Travel-time Curve Functions and Properties

The full set of travel-time functions is accessed via the **TT** pulldown (Appendix A) but a limited set can be accessed directly by left-clicking on one of the curves to invoke the Travel-time Curve Functions/Properties Pop-up (Appendix B). This menu mixes functions with properties. **Align** will align the display on the curve, **Color** sets the color of the curve, **Width** sets the width in seconds, **Slowness** will show the slowness information for the curve at the point where it was clicked on (try this!), **Raise** will put the curve in front of any others, **Lower** will put it behind, **Erase** will remove the curve from the display but not from memory, **Delete** will remove the curve from display and memory, and **Cancel** will dismiss the pop-up.

For the tutorial we want to align on P, so select **Align**. You can also align by using the **Time Alignment** option of the **View** pulldown (select **Phase** and a pop-up will appear with a list of the displayed phases to choose from). Note that once you are aligned on a phase, when you bring up the popup for that curve, instead of **Align**, you will have an **Unalign** option. Practice aligning/unaligning on each of the curves shown. For the tutorial, we will assume that the display is aligned on P, so make sure that you are in this mode before proceeding. Note however, that none of the rest of the discussion requires that the Waveform Display be in align mode: you should use whichever mode works best for the task at hand.

Changing the Viewing Reference Frame

We are nearly ready to read waveform data but as we shall see we can make our waveform request even more efficient by first zooming our display to bracket the portion of waveforms needed for the task at hand. Let us assume that for our selected event we are interested in picking P arrivals for stations closer than 100 degrees. To do this we only need to read in a small amount of waveform data around the predicted time of the P arrival.

To setup our waveform display we need to understand the rest of the Zoom Buttons (Appendix C) displayed along the bottom of the MatSeis display. The first group (**ZOOM**: **undo**, **full**, **origins**, **data**) are general zoom utilities. **Undo** simply reverts the display to whatever it was before the last zoom action. Zoom actions are stacked so selecting undo multiple times will continue to recall subsequent displays (i.e. they are fetched from a stack). **Full**, as we have seen, will zoom to a view of a selected origin just wide enough to show all of the travel time curves read in. **Origins** will zoom to a view of all origins selected for display, whether they span a range of seconds or a range of years. **Data** will zoom to show all waveform data currently in MatSeis and is most useful when no origin is selected. Note that this option can lead to considerable confusion when you are working with waveforms for events widely separated in time. The **Data** zoom will zoom to a window big enough to span all of the data which may make none of the waveforms readily visible -- if the events span several years than so will the display. The easiest way to notice this has happened is to look at the time scale along the bottom of the Waveform Window.

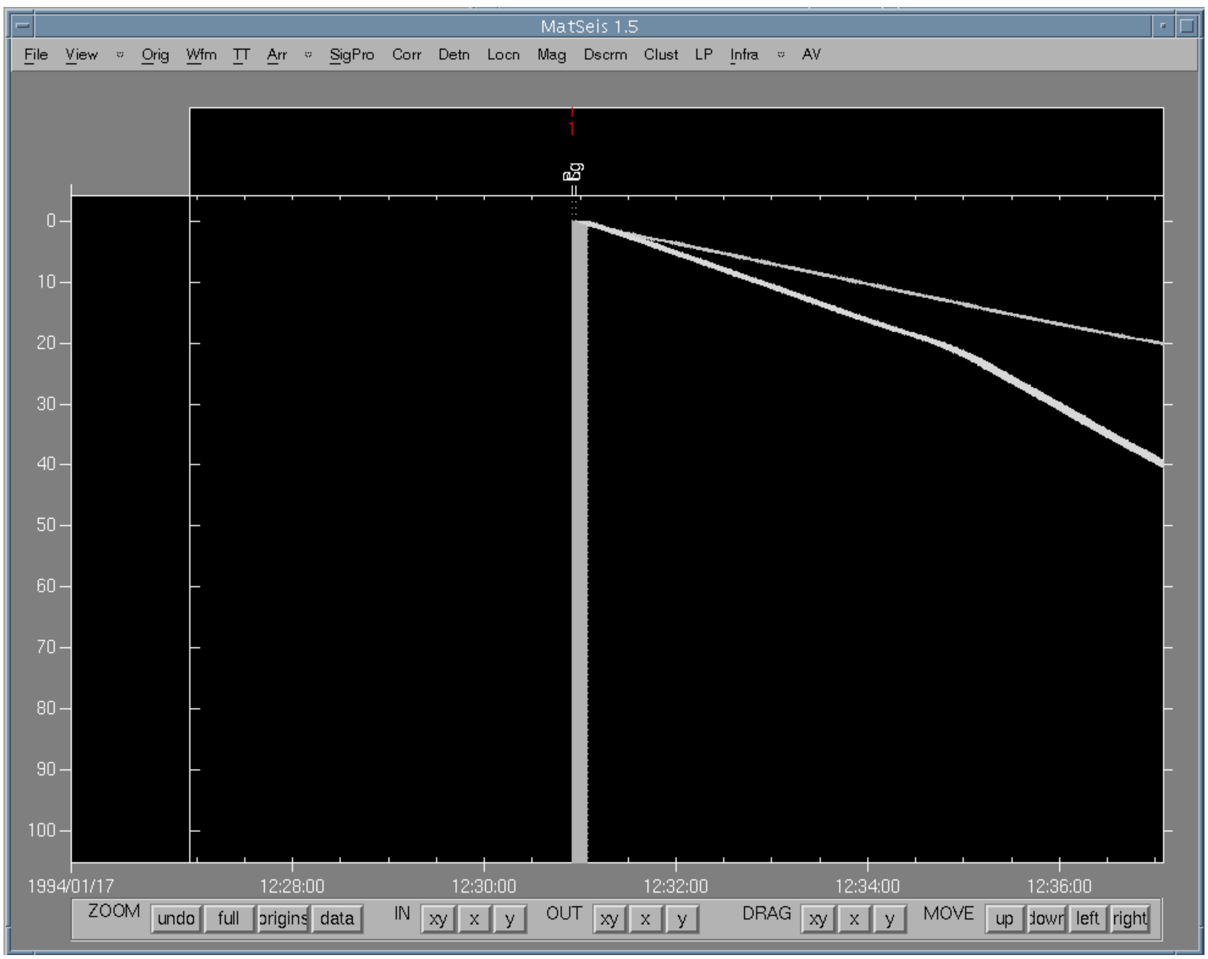
The second group (**IN**: **XY**, **X**, or **Y**) are all zoom in functions. To zoom in, select the appropriate button and a cross cursor will appear. Left-click once to choose one corner of the zoom area and hold and drag to define the other corner. Note that the method is the same whether defining a two-dimensional zoom (**XY**) or a one-dimensional zoom (**X** or **Y**). However, for a one-dimensional zoom the other rectangle dimension (y or x) will have no effect on the zoom. This style of drag-box (also known as a “rubber band box”) is used throughout MatSeis, as we shall see.

The third group (**OUT**: **XY**, **X**, or **Y**) are zoom out functions. To zoom out, simply select the appropriate button. The amount of zoom out is preset.

The fourth (**DRAG**: **XY**, **X**, or **Y**) and fifth (**MOVE**: **up**, **down**, **left**, **right**) groups are translation functions. **MOVE** is simpler but less flexible. Simply select one of the buttons and the viewing frame of reference will shift by a preset amount in the corresponding direction. The drag buttons are much more precise (and more useful). Select one of the buttons and the cross-cursor will appear. Click the left mouse button on a feature in the current display and hold and drag to the spot where the feature should be in the new display.

Become familiar with the use of the various zoom buttons by experimenting with the currently displayed travel-time curves for the selected origin. Remember to use **undo** to revert to the previous display. Now, using any combination of zoom functions you like and with the display aligned on P, zoom in to a window ~10 minutes wide centered on the P curve with the Y axis spanning distances from 0 to 100 degrees.

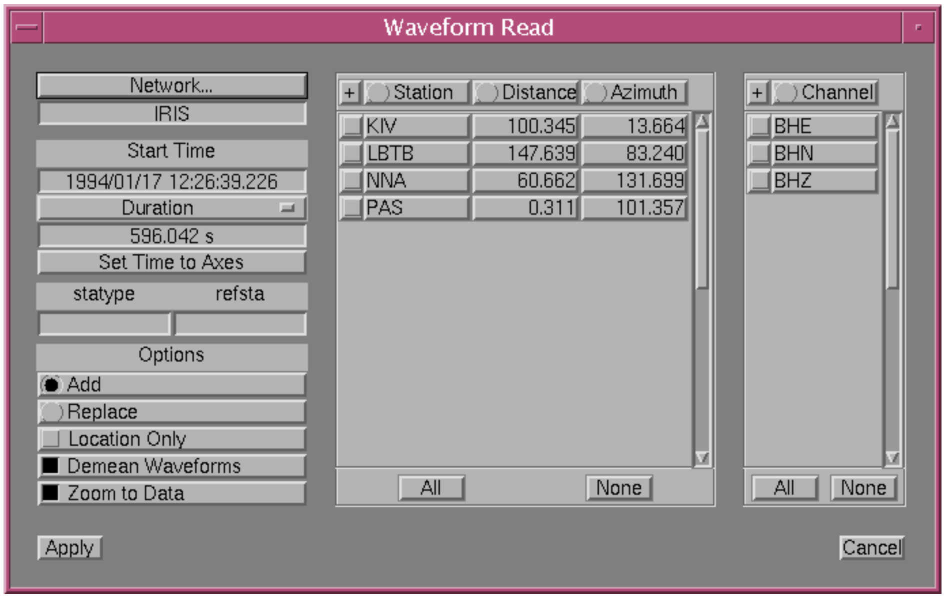
The display should look something like this.



Reading Waveforms

We are now ready to read waveform data. Select the **Read** option from the **Wfm** pulldown

(Appendix A) and the Waveform Read Window will appear. Begin by specifying the **Network**. If there is no network specified, then all of the stations will be shown. However, for the purposes of the tutorial we want to show how network information is used, so read on. You can either type the network name directly in or click on **Network** and a popup with all of the networks defined in the *network* table will be shown. In this case there should be only one: IRIS. Select it. Once the network is specified, all of the **Stations** and **Channels** in that network will be displayed (linking is done through the *affiliation* table).



Select All stations and channels or choose a specific set. Again, the lists can be sorted by the different fields and the sorting can be reversed using the **+/-** buttons. For the tutorial, select all stations within 105 degrees of the origin (i.e. distance < 105) and choose the BHZ channel only.

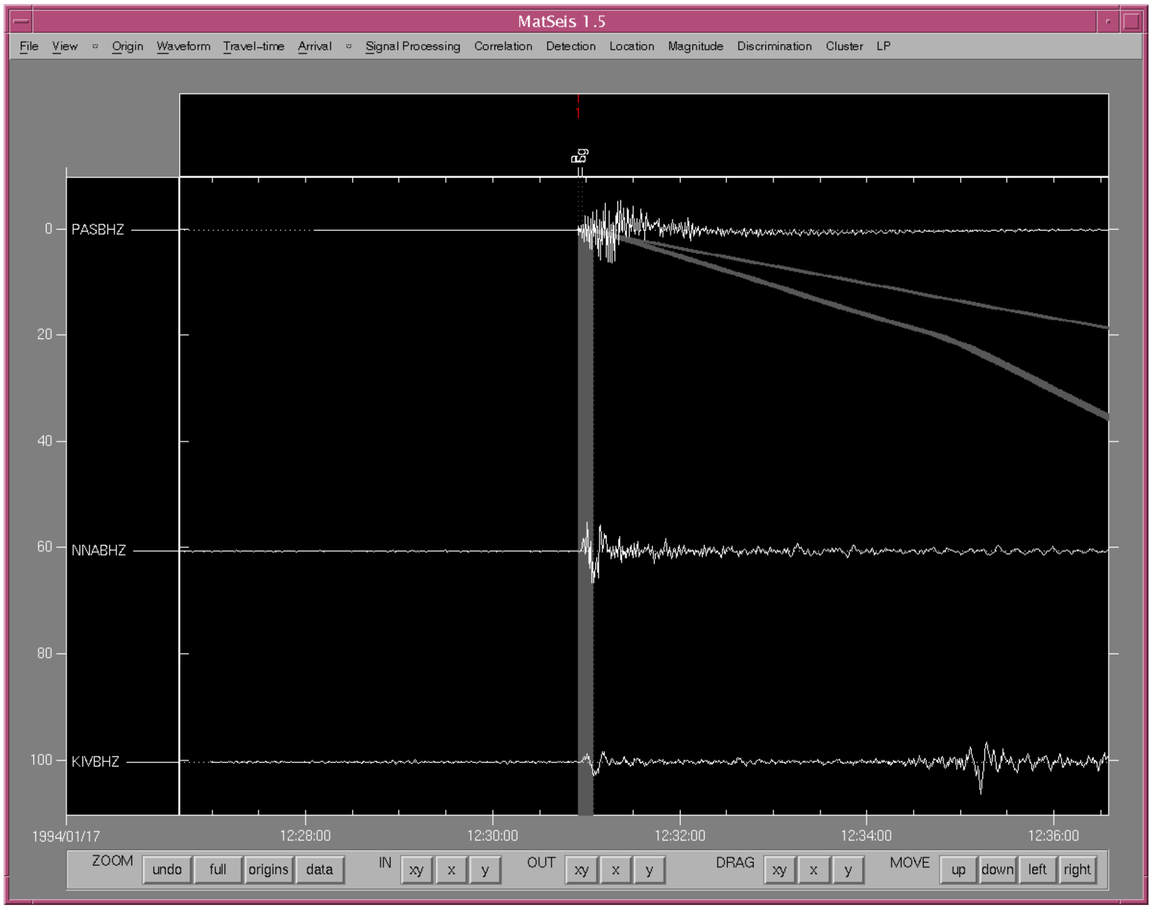
Bracket the time interval by typing in **Start Time** and **Duration** (or **Stop Time**) or use the time interval defined in the waveform window by selecting the **Set Time to Axes** button. Note, however, that this last step is unnecessary unless you change the Waveform Window while the Waveform Read Window is up: by default the time interval will come up set to the limits defined by the MatSeis Waveform Window. This is why we went to the trouble of setting up the Waveform Window before reading in any waveforms: by aligning on the P travel-time curve, and using the various zoom functions to set the window, we have made it unnecessary to type in the time limits. Note that one should always seek to read in as little waveform data as possible, as the more data that is in MatSeis the poorer the performance will be.

For an Oracle database, **statype** and **refsta** allow you to further refine the stations to choose from assuming these fields have been properly populated in the site table. The parameters have no effect for a flatfile database (like the tutorial set).

Add will add the waveforms to those already in memory, while **Replace** will replace the waveforms already read in memory. **Location Only** will plot baselines at the correct epicentral distances rather than actually reading in data (this can be useful in some unusual situations!). **Demean Waveforms** will remove the mean from the waveforms before they are plotted (useful for broadband data). **Zoom to Data** will automatically zoom the display to bracket the waveforms (if the waveforms are being added to some already in MatSeis, then the bracketing will be for all of the waveforms). For the tutorial choose **Add** and **Demean Waveforms** only.

When the stations and channels are selected and the options are set, select **Apply** and the waveforms will be read from the database and displayed.

The display should now look something like this.

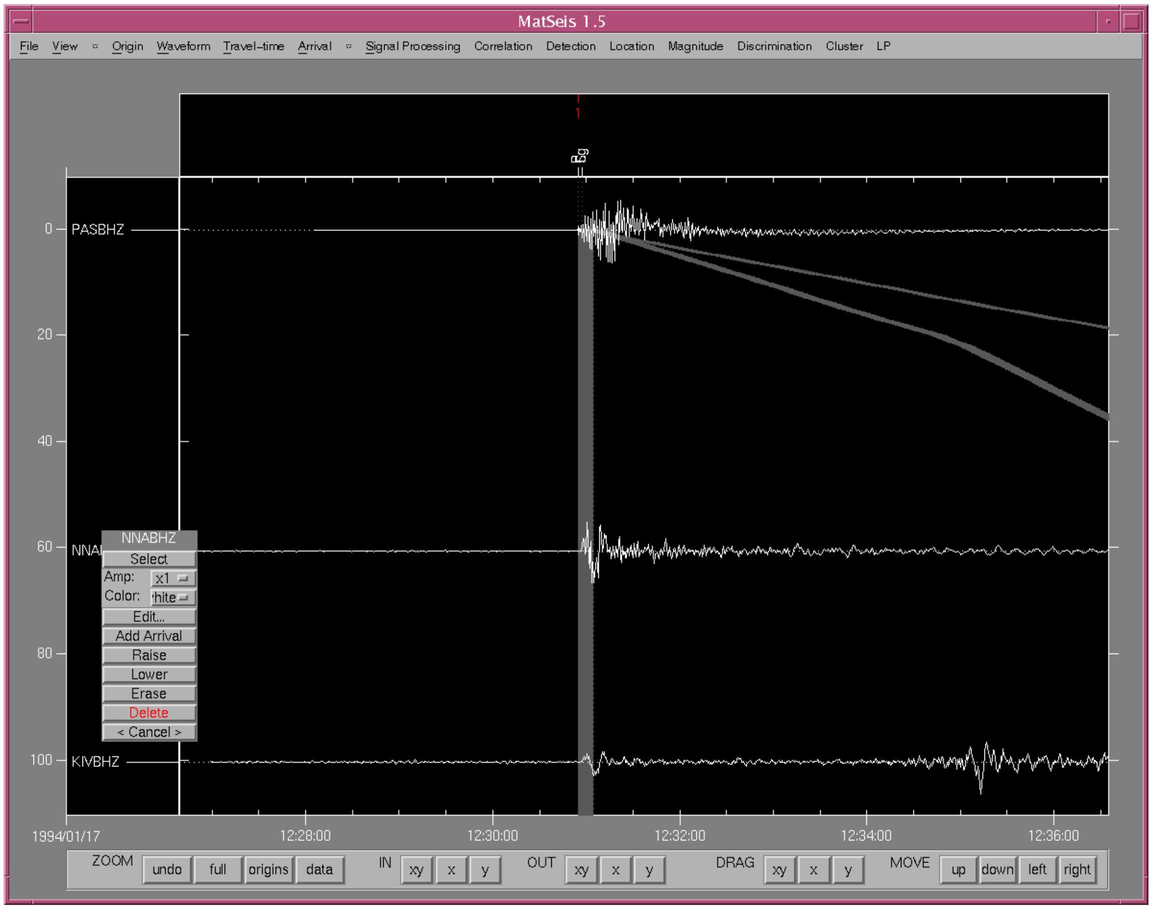


Waveform Scaling

Counter to what would be expected for stations spanning such a wide distance range, the waveforms appear to be approximately equal in amplitude, but this is only because the default waveform scaling is **automatic,** i.e. all waveforms are scaled so that their maximum amplitudes are equal. To see the true relative scaling, select the **Scaling** option of the **Wfm** pulldown and choose either **Global Fixed** or **On-screen Fixed**. **Fixed** means that the maximum amplitudes of all waveforms are scaled relative to the maximum amplitude of the largest waveform (in this case the one at station PAS). **On-screen** means that the maximum amplitudes used come from the portions of the waveforms shown on the screen, **global** means that they come from the complete waveforms, whether on screen or not. Note that for **fixed** scaling the waveforms at the two further stations become essentially flat lines, which is as expected given how much farther away they are than PAS. For the tutorial we want to see the shapes of all of the waveforms, so go back to the **Wfm** pulldown, choose the **Scaling** option, and choose **On-screen Automatic**.

Waveform Functions and Properties

The full set of waveform functions is accessed via the **Wfm** pulldown but a limited set can be accessed directly by left-clicking on one of the station names shown in the Station Information Window to invoke the Station-Channel/Waveform Information Pop-up (Appendix B):



Select will select the waveform, **Amp** will change the amplitude, **Color** will change the color, **Edit** will access waveform properties via another pop-up described below, **Add Arrival** will add an arrival at the cursor point where the left-click was executed using the **Default Phase** set in the **Arr** pulldown, **Raise** will move it in front of other waveforms (if they overlap), **Lower** will move it behind, **Erase** will hide the waveform from view but not from memory, **Delete** will remove the waveform from view and from memory, and **Cancel** will dismiss the pop-up.

Choose **Edit** to bring up the Waveform Edit Window (Appendix B). This window shows properties for both the waveform and the station/channel. All of the fields are editable. **Amplitude**, **Offset** (vertical), **Clip Level**, **Color**, **Line Style**, and **Line Width** will all affect the way the waveform is displayed. Select **Apply** after changes have been made to save them or **Cancel** if no changes are desired. For the tutorial we have no changes, so select **Cancel**.

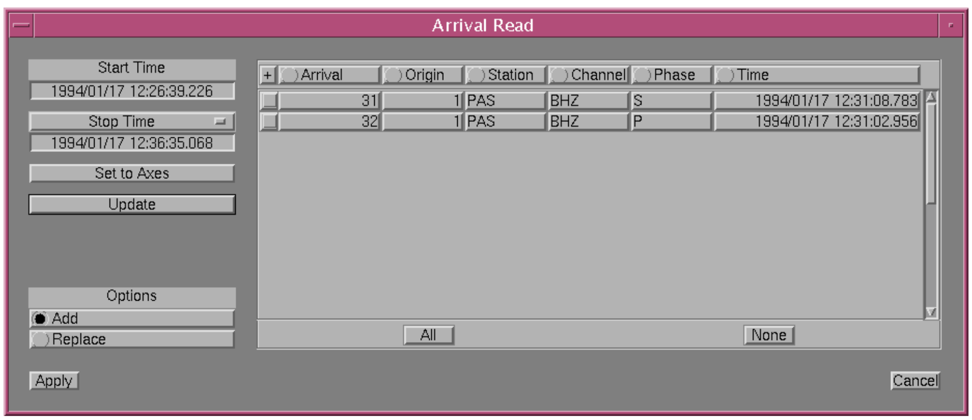
Selecting Waveforms

Waveforms can be selected using the option in the Station-Channel/Waveform Pop-up, but this is generally the least used method. To quickly select a single waveform or a small number of waveforms from the Waveform Window, type <ctrl-w> and you will get a cross cursor, ala the zoom commands. Simply drag a box to surround the waveforms to be selected (note that the box does not need to encompass the ends of the waveforms, only the vertical extent is important here). The station/channel (but not the waveform itself) will change from white to red when the waveform is selected. Practice selecting groups of waveforms. To unselect waveforms, just draw a box that does not contain any or type <ctr-n>.

When a more restrictive selection is required, the **Select->From List...** option of the **Wfm** pulldown is generally used. This will bring up a selectable list which can be sorted in many ways (e.g. by distance, by channel type). Note that the distances are epicentral distances for the currently selected origin. With this list one could, for example, quickly and easily select the BHZ channels for all of the regional distance stations for an event. Experiment with selecting, unselecting and changing the sorting of the list.

Reading Arrivals

For the tutorial we will pick our own arrivals rather than read them in. To read in arrivals from an arrival table, select the **Read** option from the **Arr** pulldown (Appendix A) and the Arrival Read Window will appear.



This display is very similar to the **Origin Read Window**. First you read arrivals from the database using the **Update** button, then you select which of these arrivals will be brought in to MatSeis. When the arrivals are selected and the options are set (**Add** or **Replace**), select **Apply**. If you want to try to read in the arrivals for the demo data set, go ahead. But after you have done this, delete them before proceeding. To do this use <ctrl-a> and drag a box to select the arrivals, then type <ctrl-g> to delete them. See the **Select** option of the **Arr** pulldown for more select options, and the **Delete** option of the **Arr** pulldown for more delete options.

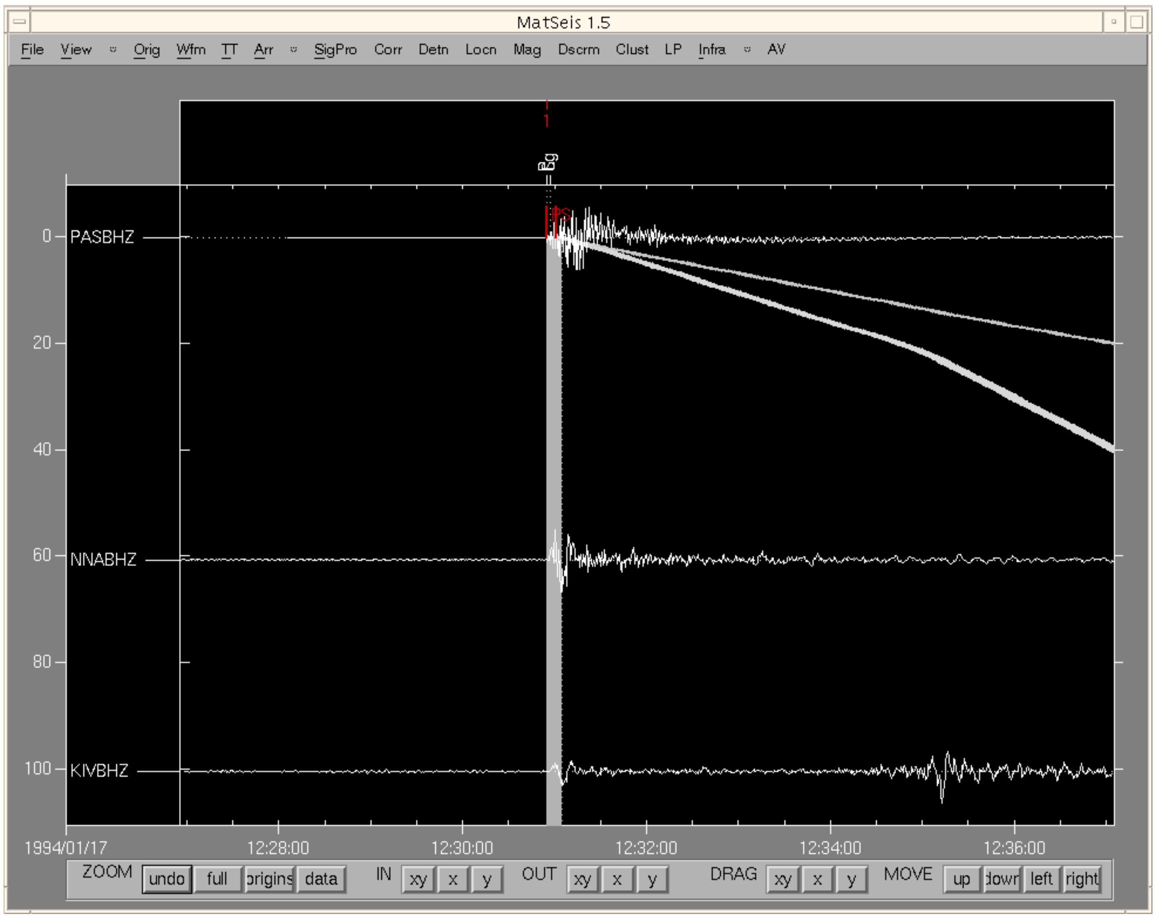
Picking Arrivals

The waveform display should now be fairly well set up to pick arrivals. If you don't mind cheating and want to pick a lot of arrivals fast, select the **Pick Travel-times** option from the **Arr** pulldown. This utility will make picks for all travel-time curve phases displayed on all waveforms displayed at the theoretical arrival times (i.e. where the travel-time curves crosses the baselines of the waveforms). This feature was added for creating synthetic data sets for testing; we do not advocate its use!.

To pick arrivals a little more carefully, first use the zoom buttons to zoom in or out to get a better view of the waveforms as needed. To pick an arrival first set the default phase type by selecting the **Default Phase** option of the **Arr** pulldown. A pop-up will appear from which the desired phase can be selected or typed-in. Note that the list of choices corresponds to the travel time curves that have been read in. For the tutorial, choose **P** from list by selecting **Apply** (which will dismiss the list), then make this the default phase by selecting **Apply** again from the default phase popup.

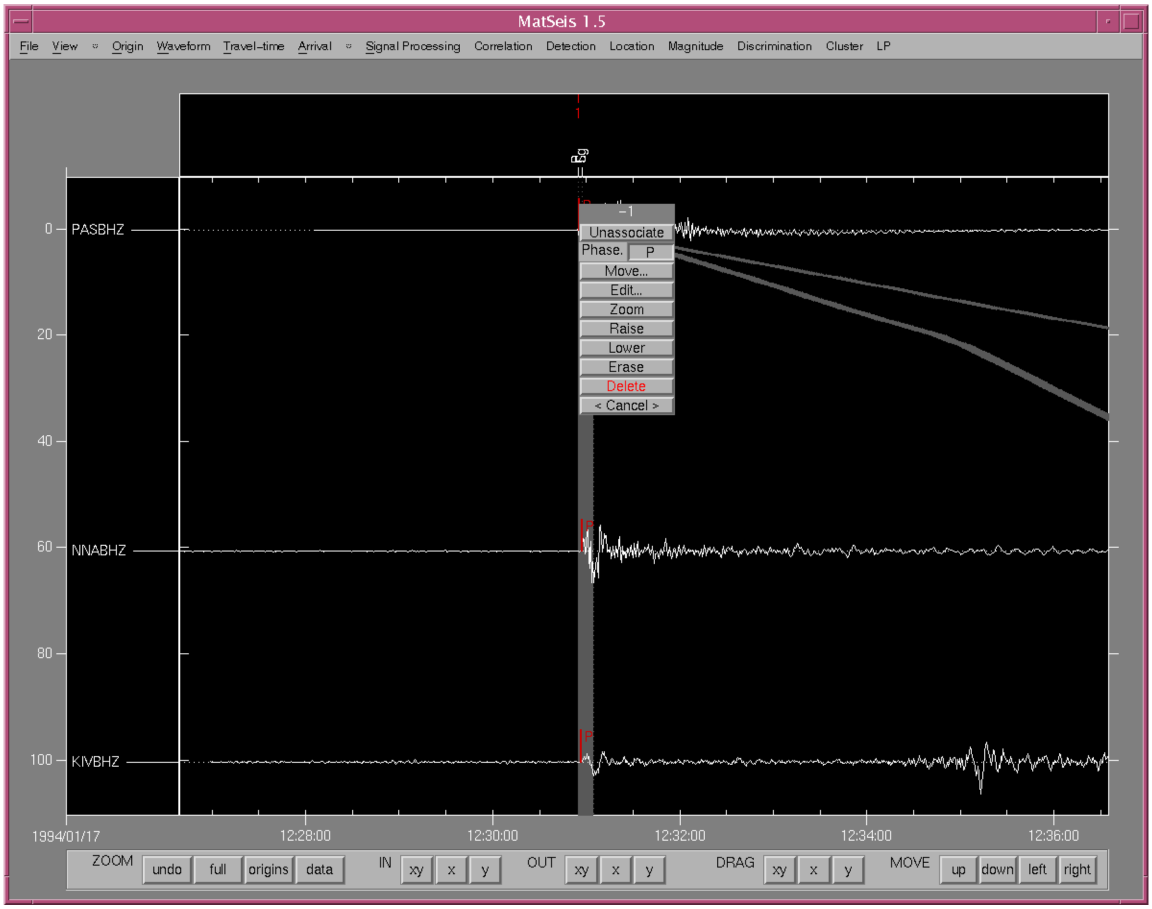
To pick an arrival, left-click on the waveform at the point you want to add the arrival and the waveform popup will appear. Select the **Add Arrival** option and a pick will be added. Note that the arrival will appear with the default phase name and will be red indicating that it is associated with the current origin (unselected arrivals are white). Pick P arrivals for all three stations, but do not worry about any errors; we will show how to fix these (e.g. retime, delete) in the next section.

Your waveform display should now look something like this.



Arrival Functions and Properties

The full set of arrival functions is accessed via the **Arr** pulldown, but a limited set can be accessed by left-clicking on the arrival to invoke the Arrival Function Pop-up (Appendix B): Try this on one of the arrivals:



Associate/unassociate will associate or unassociate the arrival with the selected origin, **Phase** will change the phase name, **Move** is used for retiming, **Edit** will access the arrival properties via a pop-up described below, **Raise** will move the arrival in front of any others, **Lower** will put it behind, **Erase** will remove the arrival from display but not from memory, **Delete** will remove the arrival from display and memory, and **Cancel** will dismiss the pop-up.

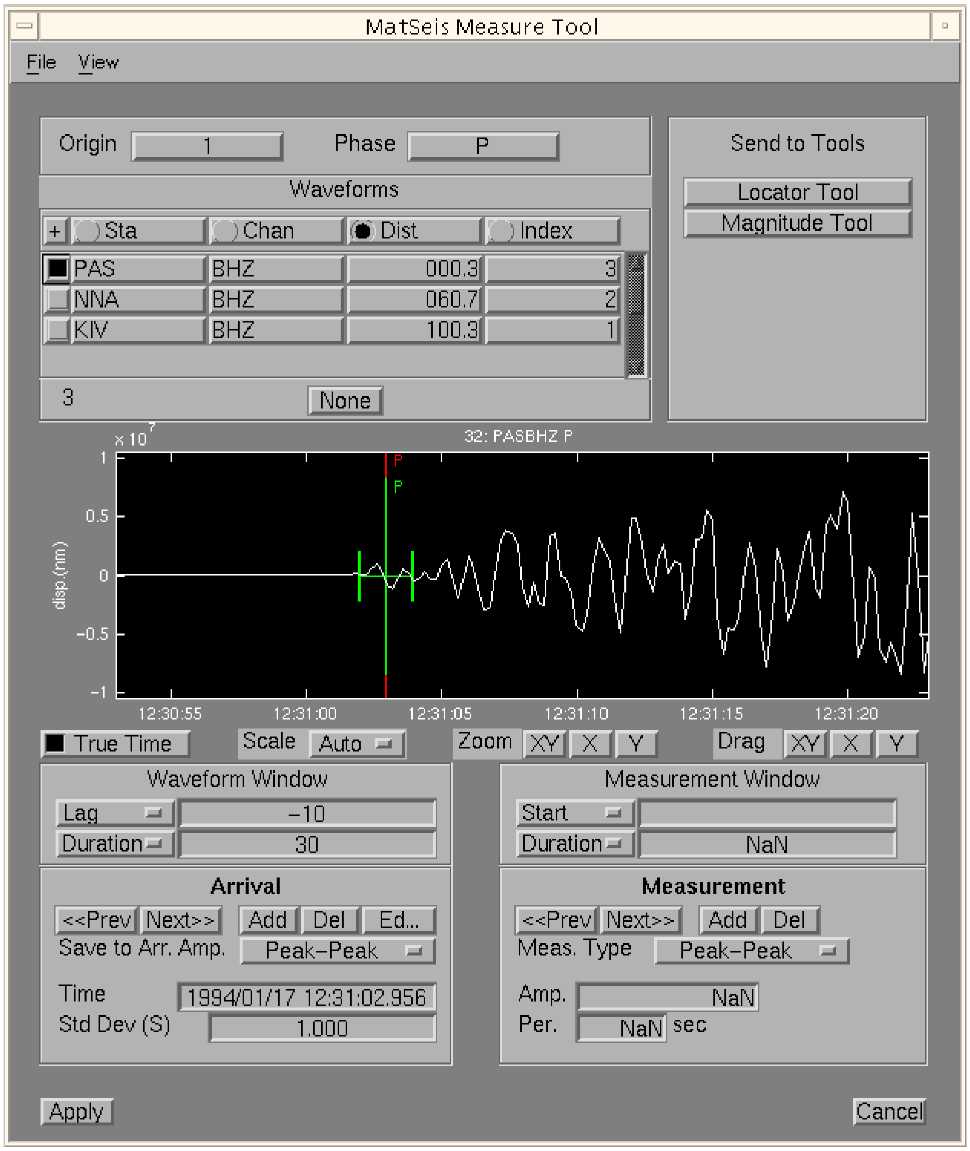
Choose **Edit** to bring up the Arrival Edit Window (Appendix B). This window can be used to review or edit any of the arrival properties, which are actually a combination of the arrival and assoc CSS3.0 tables. All of the fields are editable. Select **Apply** after changes have been made to save them or **Cancel** if no changes are desired. For the tutorial we have no changes so select **Cancel**.

To retime an arrival, select **Move**. A cross cursor will appear. Move the cursor to the new location and left-click to mark the new time. The arrival will move to the new time.

Using what you have learned above, retime all picks and delete any extras. Add picks for S and Lg. You can either change the default phase before picking these or pick them as P’s and then rename them. Note that when you rename them, you can type in whatever you like (you are not limited to the phases of the travel time curves).

Measure Tool

Though you can pick and retime arrivals within the MatSeis **Waveform Window** as described above, a better way to do it is using **Measure Tool**, which is found under the **View** pulldown. **Measure Tool** can be used in several ways. To make picks for a single waveform, select that waveform before launching **Measure Tool**. To make picks for an event, unselect all waveforms before launching **Measure Tool**. For the tutorial, let's work on the whole event so unselect all of the waveforms by using <ctrl-w> and dragging a box which does NOT contain any waveforms (or using the **Select->None** option of the **Wfm** pulldown, which can be triggered using <ctrl-n>). Then type <ctrl-m> to launch **Measure Tool.**



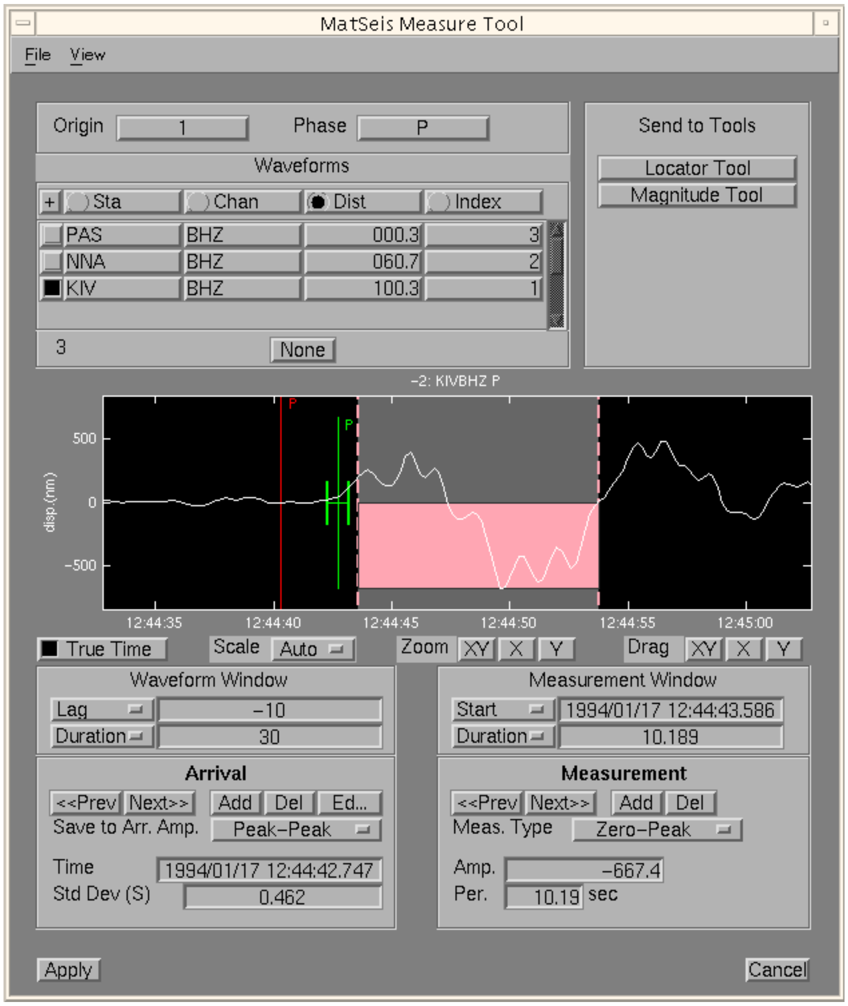
Near the top of the tool is a list of the waveforms for the event. As we have seen for other types of lists, you can sort on any of the quantities on the list by clicking on the header for that quantity (e.g. Distance), and you can reverse the order of sorting by clicking on the + button to change to - or vice versa. Sort by distance and then select the closest waveform (PAS). The waveform for

PAS will appear in the waveform window. This display should look something like that shown above. Note that the units for the waveform are labelled on the y axis. By definition these should be *nm* because the raw data, which is in counts, is multiplied by the calib field from the wfdisc table when the data is read into matseis, and calib is defined to have units of nm/count. Of course these units are only truly correct for the calper (calibration period, also given in the wfdisc) corresponding to the calib values unless the waveform has had the instrument response deconvolved.

The **red bar** is the theoretical arrival time for the currently selected phase as shown in the **Phase** popup near the top. The list of possible phases comes from the travel time curves in MatSeis and the sorting is alphabetical. Thus, for the tutorial Lg is the current phase. Let's change this to P. To do this click on the current phase (**Lg**) and a popup will appear. Select **P** and then **Apply**. The phase should now be switched to P. Referring back to the waveform window below, it should now be centered on theoretical P. The **green bar** is the P pick (assuming you have made one in the MatSeis Waveform Window), and it includes an **error bar**. To retime the arrival, simply left click and hold on the picked arrival and move it, then release the button when you have the pick at the desired time. You can adjust the error bar in the same fashion, by grabbing either side of the error bar and stretching/compressing as much as desired. Notice that the **Time** and **Std Dev** displays in the lower left change as these are adjusted. The **Zoom** and **Drag** buttons for the waveform display work much the same as for the MatSeis Waveform Window except that these are "sticky" (i.e. they stay selected until you unselect them. Note that if you zoom in or out the **Lag** and **Duration** values will change. You can also type these in directly and the waveform window will change accordingly. If you prefer not to work with **Lag** and **Duration** you can toggle these to **Start** time and **Stop** time. The **Scale** buttons control whether or not the waveform is automatically scaled whenever you shift/zoom. The **True Time button** alternates between true time and time relative to the picked time (try it!). Use whichever of these buttons you like to help you refine both the pick and error bar for PAS.

To move on to the next station (NNA) there are a couple of options. First, you could go back to the list at the top and select NNA. Alternatively, you can press the **Next>>** button in the **Arrival** section of the tool to move to the next waveform in the list. (**<<Prev** will shift back to the previous waveform, if there is one). Try all of these to switch back and forth between waveforms. Once you have NNA displayed, we can add a pick (if NNA did not have one already). To do this simply choose the **Add** button in the **Arrival** section. This will change the cursor to a cross-hairs in the waveform window, and you can now click wherever you want the new pick to be. Add a pick in this manner, and adjust the error bars to be appropriate for the resolution of your pick. To delete an arrival, just push the **Del** button. To review (and edit if you wish) all of the properties for an arrival select the **Ed...** button. The **Save to Arr. Amp.** popup lets you choose which type of measurement (described below) will be saved to the amp field of the arrival (only one value can be stored in this field). This is important because the **Magnitude Tool** will base its calculations on this amp field.

Using what you have learned, move on to the KIV waveform and add a P pick. Let us now make an amplitude measurement to go with this pick. (Note: you cannot make amplitude measurements unless you have an arrival, so make sure you have one for KIV before proceeding!). This is done using the controls in the area labelled Measurement. You can choose the type of measurement using the popup menu labeled **Meas. Type**. We will choose **Zero-Peak** for the tutorial. To make the measurement, choose the **Add** button, and the cursor will change to a cross in the waveform window. Simply drag a box (ala the zoom functions) to encompass the maximum peak (or trough) that you want to measure. Two boxes will appear. A gray one showing the entire measurement window and a pink one showing the measurement itself. The amplitude and period (in this case the length of the measurement box) are shown in the labelled **Amp** and **Per** areas below.



If you missed the peak you wanted, you can slide or resize the measurement box by clicking and holding on either the middle or the side of the gray measurement window and moving it. Notice that as you move the window, the pink box automatically snaps to show the new peak and that the amp and per values change. If you want to delete the measurement, push the **Del** button and the gray measurement window and pink box will disappear. For measurements, the **Next>>** button will move to the next type of measurement from the popup menu and **<<Prev** will move to the previous one. You should be able to make any of the measurement types except **Peak-to-Peak** for the demo data set. This is because Peak-to-Peak measurements will be automatically corrected for instrument response using the period between the peak and the trough and this will lead to an error for the demo data set because the instrument and sensor tables were not set up and no instrument response files are provided for these waveforms. Using what you have learned, go back and make Zero-Peak measurements for NNA and PAS. When you are finished, select **Apply** to save

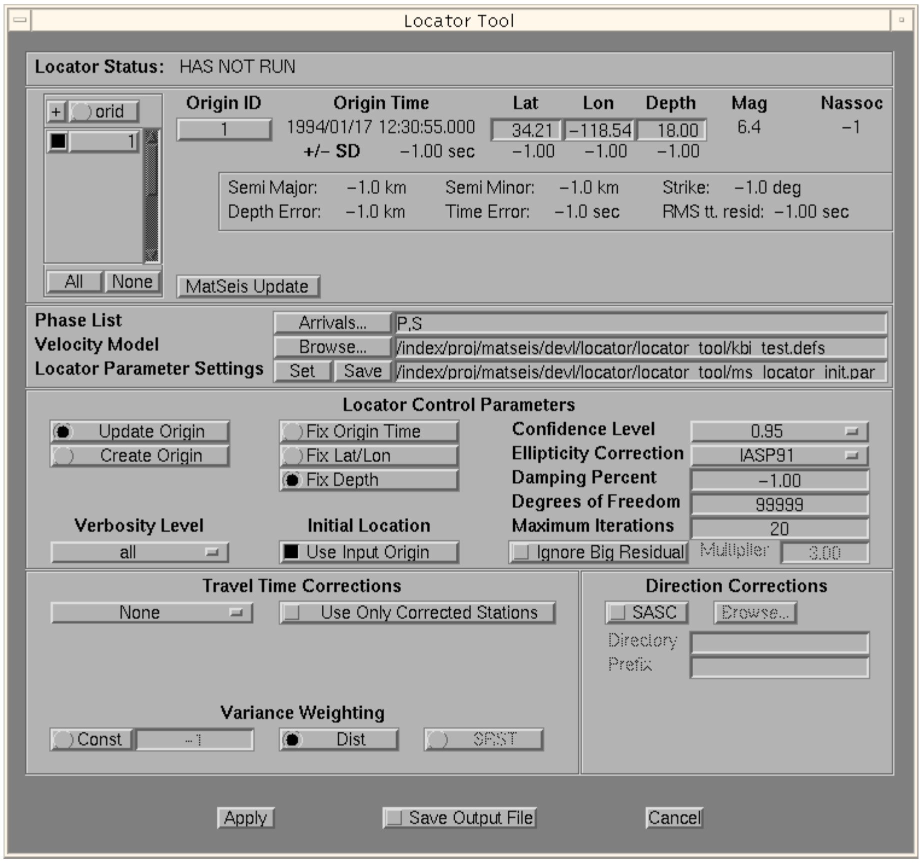
the measurements and new picks back to MatSeis.

This completes the basic tutorial on **Measure Tool**. Were more origins read in to MatSeis, you could switch to another origin by clicking on the **Origin** popup at the upper left and choosing the next one you wanted to work on. The **Send to Tools** buttons in the upper right are for sending added/modified values to the **Locator Tool** and the **Magnitude Tool**, which will be discussed in the next sections.

Locating Events

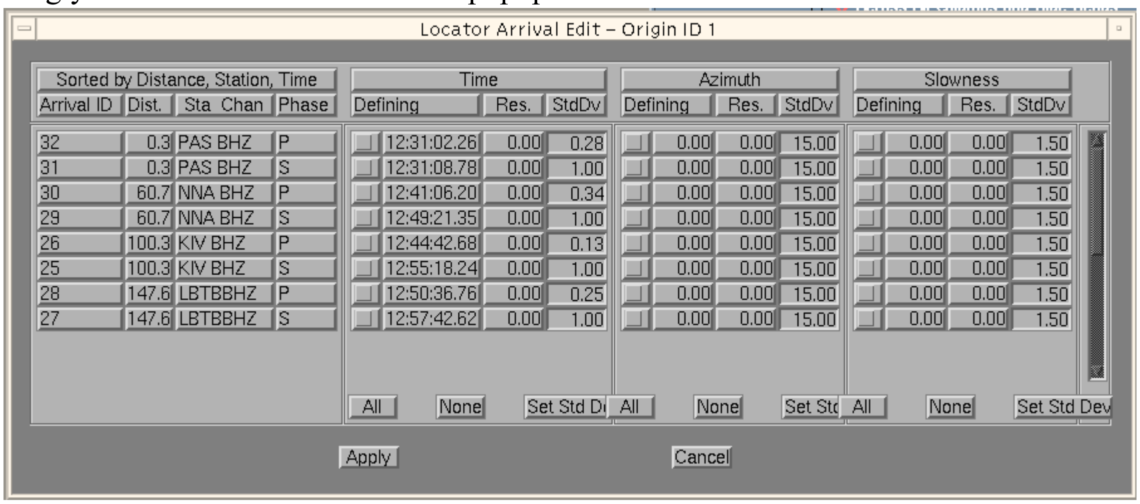
CAVEAT: the **Locator Tool** will only work for UNIX platforms because it links through the cmex interface to C code which has not been ported to PC's or mac's. This is regrettable, of course, but the amount of work involved in porting the code is well beyond our resources if it is even possible. A general purpose locator written entirely in matlab would be an excellent addition to MatSeis.

The **Locator Tool** can be launched from the **Locn** pulldown, or from **Measure Tool** if you already have that up. We will do it the latter way for the tutorial. Using **Measure Tool**, pick P arrivals and set reasonable standard deviations for the 4 stations. Now we should be ready to locate. Click on the **Locator Tool** button in the **Send to Tools** area of **Measure Tool**. Presently the **Locator Tool** should popup.



Clearly this interface has an abundance of controls and parameters. We will begin in the upper left, with the list of orids. In our case, there is just one (#1), and it should be selected, but if there were more than one origin in MatSeis, all would be listed here and the selection of the radio button to the left of each determines which ones will be located when you run the locator (done by clicking on the **Apply** button at the bottom left). Thus, you can locate several events at once. To the right of the list is a button beneath a heading labelled **Origin ID**, which should read “1” for our origin. This shows which of the origins in MatSeis we are currently displaying information for. To change the origin, click on the button and a popup will allow you to choose from the complete set of origins. Try this, but in our case there will just be one to pick from. All of the origin and origin error information displayed to the right and below this button are for the indicated origin, and these values would change if you were able to pick another origin. the **MatSeis Update** button will re-read data from MatSeis in the case new origins have been added since the **Locator Tool** was brought up.

We will now review the arrivals being used to locate this event. To see these, click on the **Arrivals...** button on the row labelled "Phase List". Notice that by default, all phases for which you have picks will be in this list. If you only want to look at certain phases you can edit this list accordingly. You should now see another popup list of the arrival information:



This list should hopefully be fairly straightforward. There is a row for each arrival picked and the display is divided into four segments left to right. The first gives the general information for the arrival (ID, distance, station, channel phase). Note that you can sort the list by any of these by clicking on the corresponding column heading. Try sorting by distance. The next area shows the time pick information: time, residual (obs. - theoretical), std. devn. (i.e. picking error). The next area shows corresponding information for azimuth and the final one shows slowness information. Azimuth and slowness are included because the locator allows the use of these two additional types of information, if they are available. You select which type of information will be used for each arrival by selecting the radio button to the left of each row in each of the data type areas. For our demonstration, select Time for the P phases only. Sorting by phase may make this easier if you have any phases other than P. You can also set the Std. Devn. values here by typing them in, if you like. The **Set Std Dvn** buttons at the bottom of each data type area allow you to do batch replacements, which is handy for data that comes in with null (e.g. -1.0) Std. Devn. values (this can lead to problems when locating the event). When all is set as you like, select **Apply** to dismiss this popup and return to the **Locator Tool**.

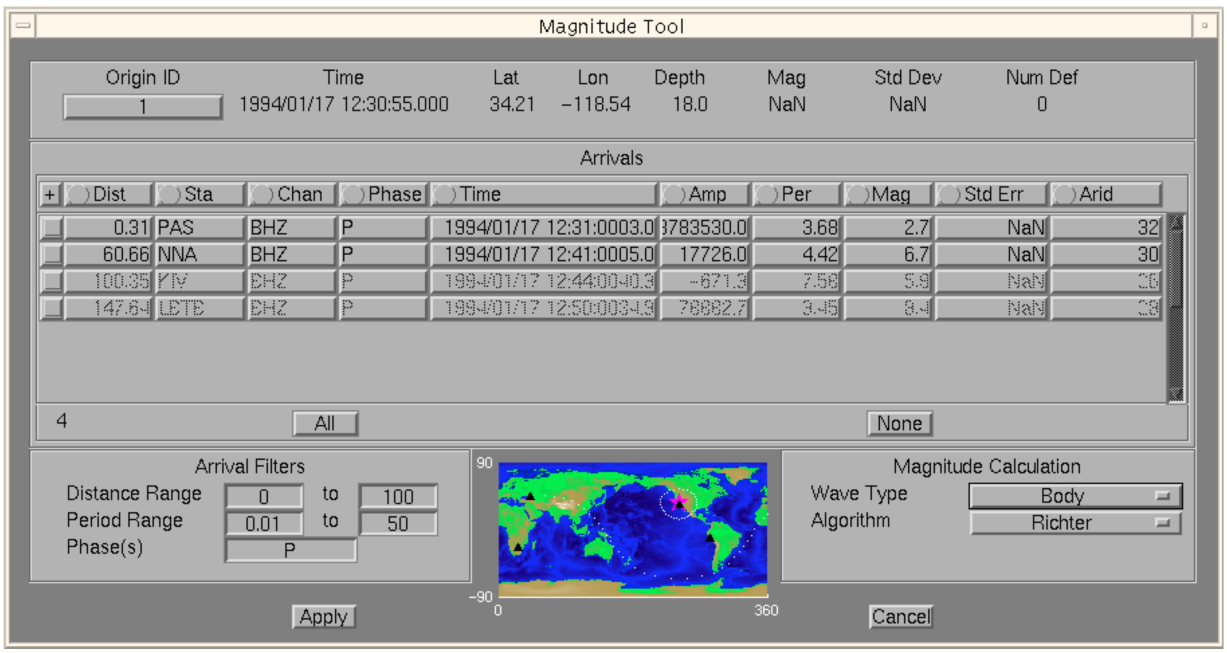
Below **Phase List** are rows for the **Velocity Model** (actually the "VMSF" file) and the **Locator Parameter Settings** (i.e. the "par" file). Both of these point to default files within the MatSeis release, but you can change them to point to files of your choice. We recommend using the existing files as templates from which to add your own customizations. Note that the location of both of these files can be set in your config file (see Appendix D).

Next we have a whole series of **Locator Control Parameters.** These all come from the **Locator Parameter Settings** file referred to above, and should be straightforward if you have ever run EvLoc or LocSAT. If you have either of these codes installed on your system, try the man pages for more information on what these settings mean. When you have the parameters set the way you want, you are now ready to locate the event. To do this, click on the **Apply** button. Two things should happen. First, a window will popup labelled Origin Output which will show you the standard output for EvLoc/LocSAT. Second, the origin information at the top of the Locator Tool should change to reflect the new location. Probably the most important thing to change will be the **Locator Status** string located at the top of the **Locator Tool** window. We hope it will say "*Successful convergence achieved!*", but there is no guarantee. If there was a problem (say not enough data), the message up here may help you figure out what to do next.

If you want to add an arrival for another station and add it to the calculation of the location, or you want to retime one of the stations already being used, just go back to **Measure Tool**, add/retime the arrival, and then click on the **Locator Tool** button again and the information will be updated in **Locator Tool**.

Calculating Magnitude

The tutorial data set is not well-suited to calculating magnitude due to the lack of instrument and sensor tables and corresponding instrument response files which are needed to convert measurements to true ground motion units. However, we can still use it to illustrate the basic procedure. Begin by using **Measure Tool** to making Zero-Peak P measurements for all 4 stations (just pick the largest peak in the first 5 seconds or so after the first arrival). Next set the **Save to Arr. Amp.** popup to **Zero-Peak.** Now click on the **Magnitude Tool** button in the **Send to Tools** area. The **Magnitude Tool** should popup presently. (It can also be launched from the **Mag** pulldown menu). Note that it does not show the measurements we have just made. This is because by default it comes up using a Surface wave formula that looks for LR phases. In the **Magnitude Calculation** area, click on the **Wave Type** popup and select **Body** (instead of **Surface**). The **Algorithm** will automatically switch to Richter, but if you wanted to use a different body wave formula you could click on this popup and choose another one. Now the measurements for the 4 stations should show up in the list and the thumbnail map in the lower center will expand its view enough to show all 4 stations and the event:



You will probably notice that some of the station lines in the list are "grayed out". This is because the **Arrival Filters** as set are excluding them. Compare the ranges of acceptable values for **Distance Range** and **Period Range** with the distance and period values for the measurements to see why they are grayed out. Try changing the filter ranges to encompass the grayed out values and see what happens. Note that **Phase** is also a filter which you can type in by hand and that you can use a comma separated list if you want to use more than one phase.

We now have individual magnitudes for each of the stations (though quite possibly nonsensical values due to the "periods" we are using), but no overall magnitude for the event, as shown in the origin line at the top. This is because none of the stations has been selected yet to use for the network magnitude. To add stations to the network calculation, just click on the radio button to the far left of each in the list. As you do, you will notice that the network magnitude and std. devn.

change and also that the triangle symbol for that station in the map changes from black to yellow, so you can get a crude idea of the station coverage.

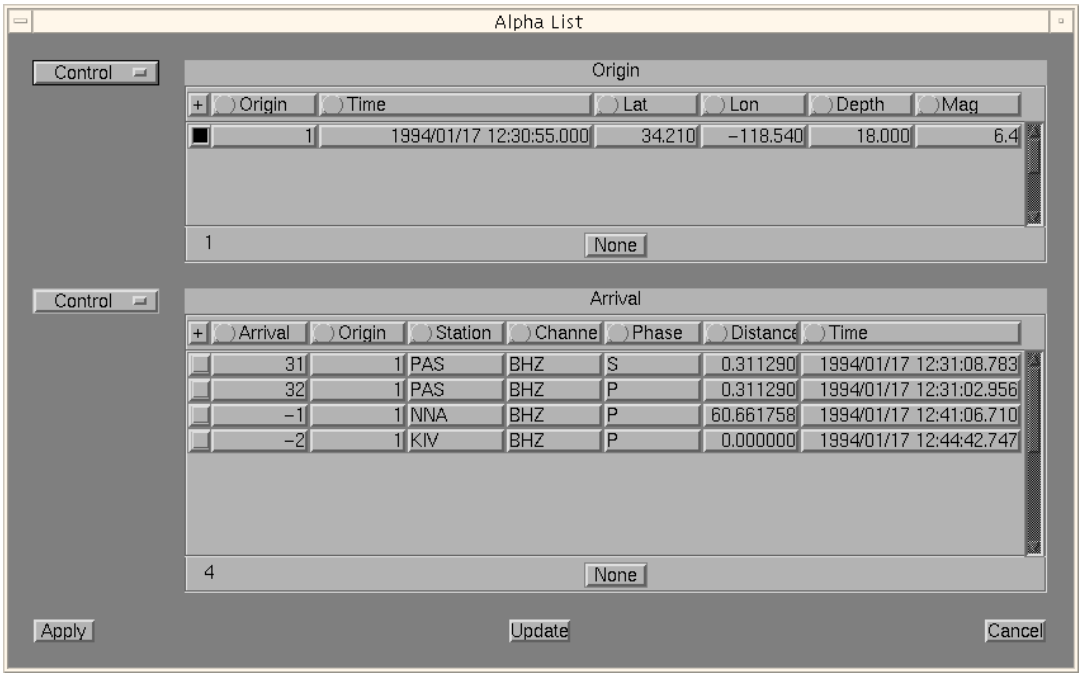
If you want to make a measurement for another station and add it to the calculation of the magnitude, or you want to remeasure one of the stations already being used, just go back to **Measure Tool**, make the measurement, and then click on the **Magnitude Tool** button again and the information will be updated in **Magnitude Tool**.

General Purpose Utilities

There are several general purpose utilities which may prove useful in your analysis. We discuss some of these here.

Alpha List

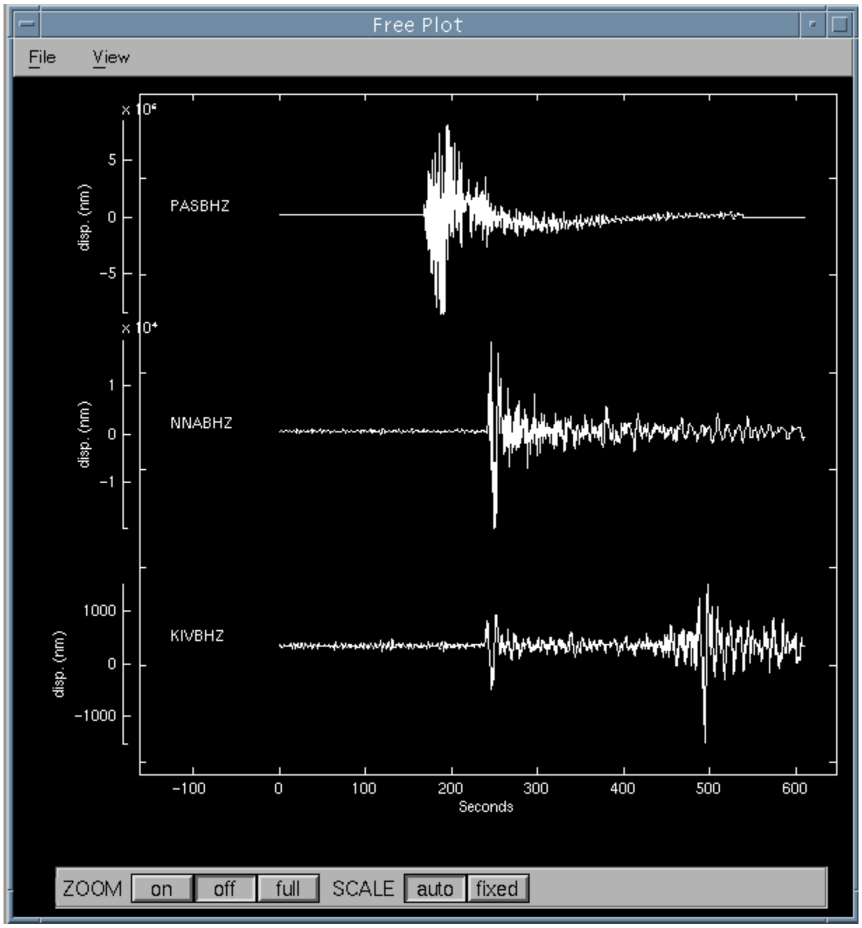
There are actually two alphanumeric lists, one for origins and another for arrivals that are linked. You will find the tool under the **View** pulldown menu. Once the tool is launched, select origin 1 (the only choice for the demo data set) and you should get displays like these:



The basic lists provided a nice means to quickly review the various quantities associated with the origins and arrivals simultaneously, but the tool allows you to do more than this. If you have an origin selected, you can click on the **Control** button next to the **Origins** list and access a set of actions to perform on the chosen origin (**Select, Edit, Zoom, Delete**). Similarly, if you select an arrival in the **Arrivals** list, you can access similar actions by clicking on the other **Control** button. In some cases, it is easier to work from the main MatSeis display and in some cases from lists, hence we provide this tool.

Free Plot

Free Plot is also found under the View pulldown menu. The purpose of **Free Plot** is to present waveform data in a manner that is less restrictive than the main MatSeis **Waveform Window**. As an example, select all 3 waveforms in the matseis window and launch **Free Plot.** You should get a display that looks like this:



Notice that the units for the waveforms are displayed in **Free Plot**. The default scaling is **auto** but you can change to **fixed** by choosing the corresponding button. You can also turn on zooming with the **Zoom On** button. Left click to draw a box to zoom and right click to unzoom. To turn zooming back off select the **Zoom Off** button. **Free Plot** also has a nice feature for comparing waveforms. With **Zoom Off** selected (it has to be or you will accidentally zoom in the next step), you can click and hold on any of the waveforms and move it horizontally or vertically anywhere in the display. Try this to compare waveforms. Note that this is most effective if you have set the waveforms to different colors in the MatSeis **Waveform Window** because **Free Plot** will use the same colors as in MatSeis.

Free Plot comes in very handy for looking at waveforms which have been plotted on top of each other in the matseis display, something which happens any time you have an origin selected and you have more than one waveform (e.g. multiple channels) for the same station. Just select all the stacked waveforms using <ctrl-w> and send them to **Free Plot**. Note also that you can select waveforms from within **Free Plot** using <ctrl-w> the same way as in the MatSeis Waveform

Window and that you can then delete them using <ctrl-e>, also as in MatSeis. Note that the selections or deletions will apply to MatSeis as well as **Free Plot**! Thus, this provides a handy way of selecting just one of a set of stacked waveforms in MatSeis (e.g. for **Signal Processing**), but it could also lead to accidental deletion of waveforms in MatSeis if you are not careful.

Signal Processing

A variety of common signal processing tasks can be accomplished using the **SigPro** pulldown.

Waveform Selection

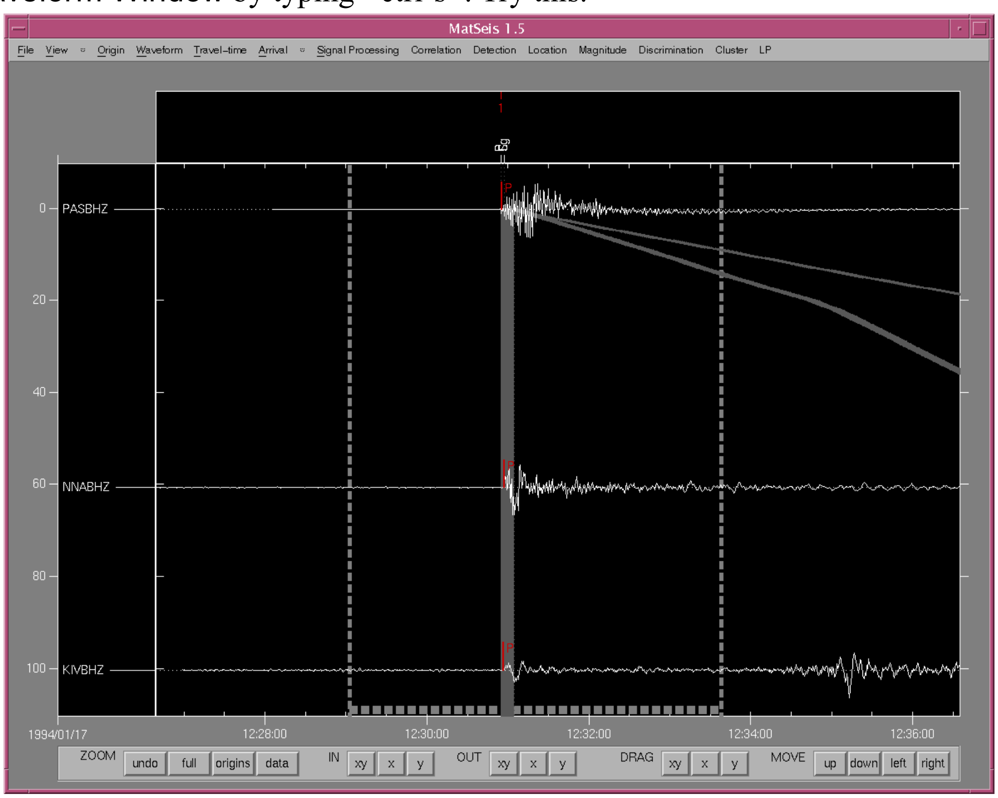
To perform almost all of the functions, you must first select the waveforms which are to be operated on. Using one of the methods already learned for selecting waveforms, select all three of the waveforms shown for the Northridge event.

Output: Create New Waveforms or Replace Existing Waveforms?

Depending on the situation you may want to simply replace the original waveforms with the processed waveforms (e.g. for demeaning) or you may want to create new ones (e.g. for comparing the effects of different filters). Either option is available through the **Options** item of the **SigPro** pulldown. For the tutorial choose **Create New Waveforms** (this should be the default setting), as we do not want to lose the original waveforms.

Setting the Time Interval for Processing

The processing can be applied to the entire selected waveform or to some specified interval via the **Time Segment** menu of the **SigPro** pulldown. the default is **Off** which means the whole waveform will be processed. There are several different methods you can choose for setting a time segment for processing. **Setup** pops-up a window which allows you to type in the time limits, but we seldom use this method. **Pick Using Mouse**, the most useful option, allows the user to set the segment lines using the mouse to drag a box, and this option can also be invoked directly from the matseis Waveform Window by typing <ctrl-s>. Try this.



The display should look like that shown above. The grey dashed lines indicate the time window for analysis. Once these are visible you can adjust them by left clicking, holding down the button, and grabbing either the left or right and moving it. Release the button to fix the new position. Note that you can also slide the whole segment window by “grabbing” the horizontal dashed line at the bottom of the screen in a similar manner.

A final means to set the segment lines is using **Set to Axes,** which will set them to the limits of the Waveform Window. Regardless of which method you use, selecting **Off** reverts to the default behavior (time segmenting turned off) and this can also be done using <ctrl-q>.

For the tutorial, we have only a small section of waveforms read in so we will select **Time Segment->Off**. For longer waveforms, however, we highly recommend windowing the section of interest using <ctrl-s> to avoid unnecessary processing.

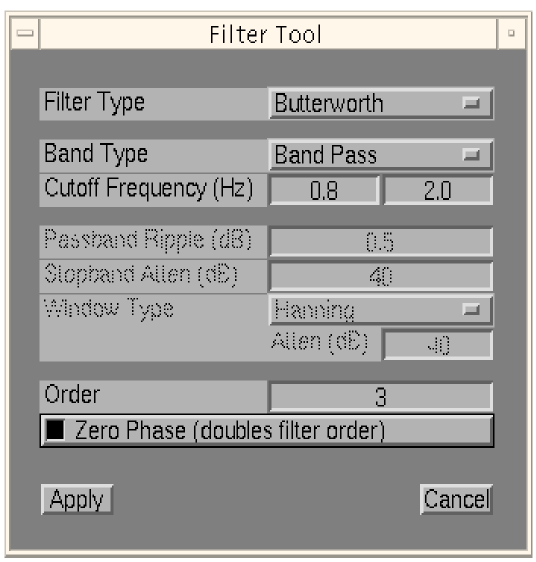
Signal Processing/Analysis Applications

At this point you are ready to process the selected waveforms. You can select from among the many options in the **SigPro** pulldown (Appendix A). The best way to learn about these functions is simply to try them on data. The function of most them should be clear to anyone with some experience in seismic data analysis. Many do nothing more than call a basic MATLAB function.

To help in getting started, we provide a few examples on the following pages.

Example 1: Filtering

As an example of one of the more commonly used functions, choose **Filter Design** from **Filters**. A pop-up will appear which allows the user to design a custom filter and apply it to the selected waveforms.

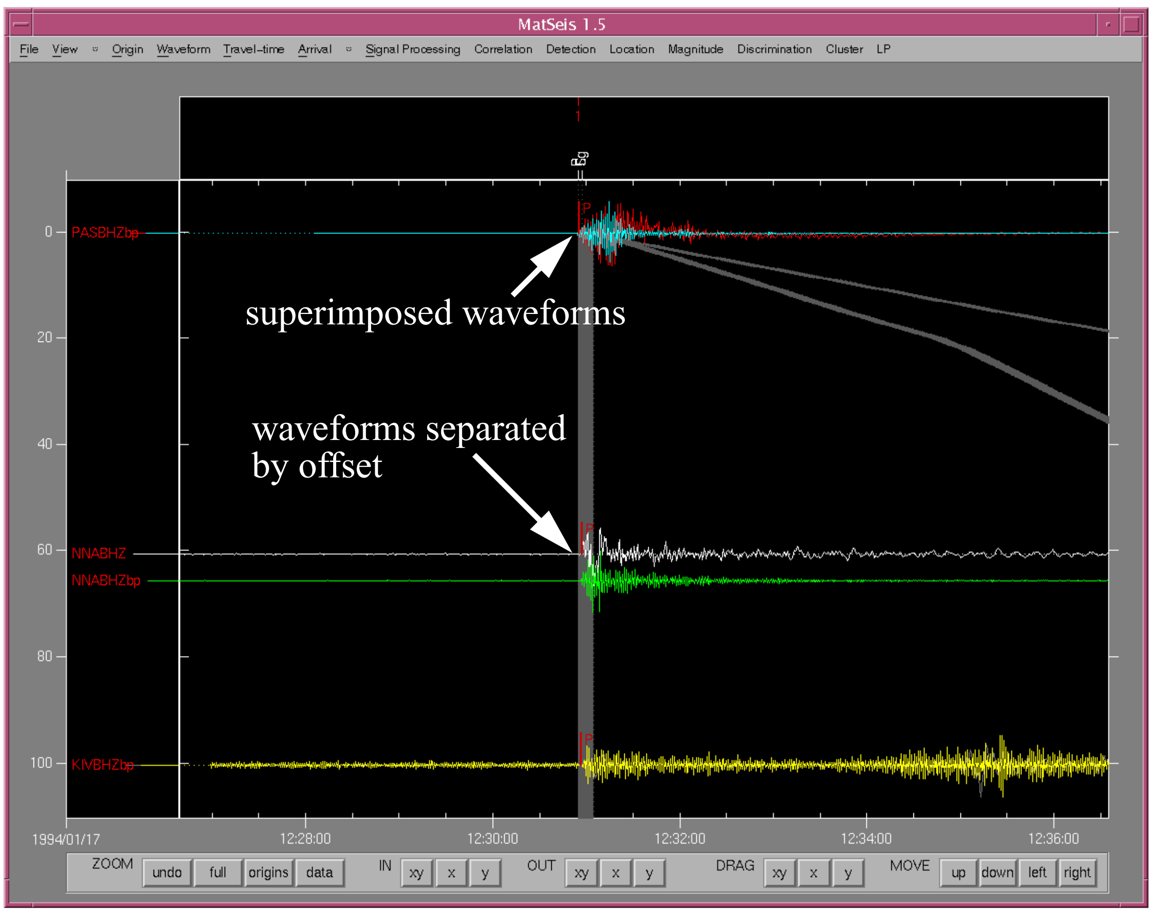


This function is an excellent illustration of the power that MatSeis has due to the underlying MATLAB code. The only code developed for this function was that necessary to set up the popup GUI; all of the filtering is standard MATLAB (plus the MATLAB Signal Processing Toolbox).

For the tutorial select all of the waveforms (if they are not already), and design and apply a Butterworth, Band Pass, 0.8 - 2.0 Hz, Order 3, Zero Phase filter. You should now have six waveforms displayed, but this may not be evident because the filtered waveforms will be plotted on top of the raw waveforms (they have the same epicentral distances). Note, however, that the station/channel identifiers of the new waveforms end in "bp" for band-pass.

Separating Super-imposed Waveforms

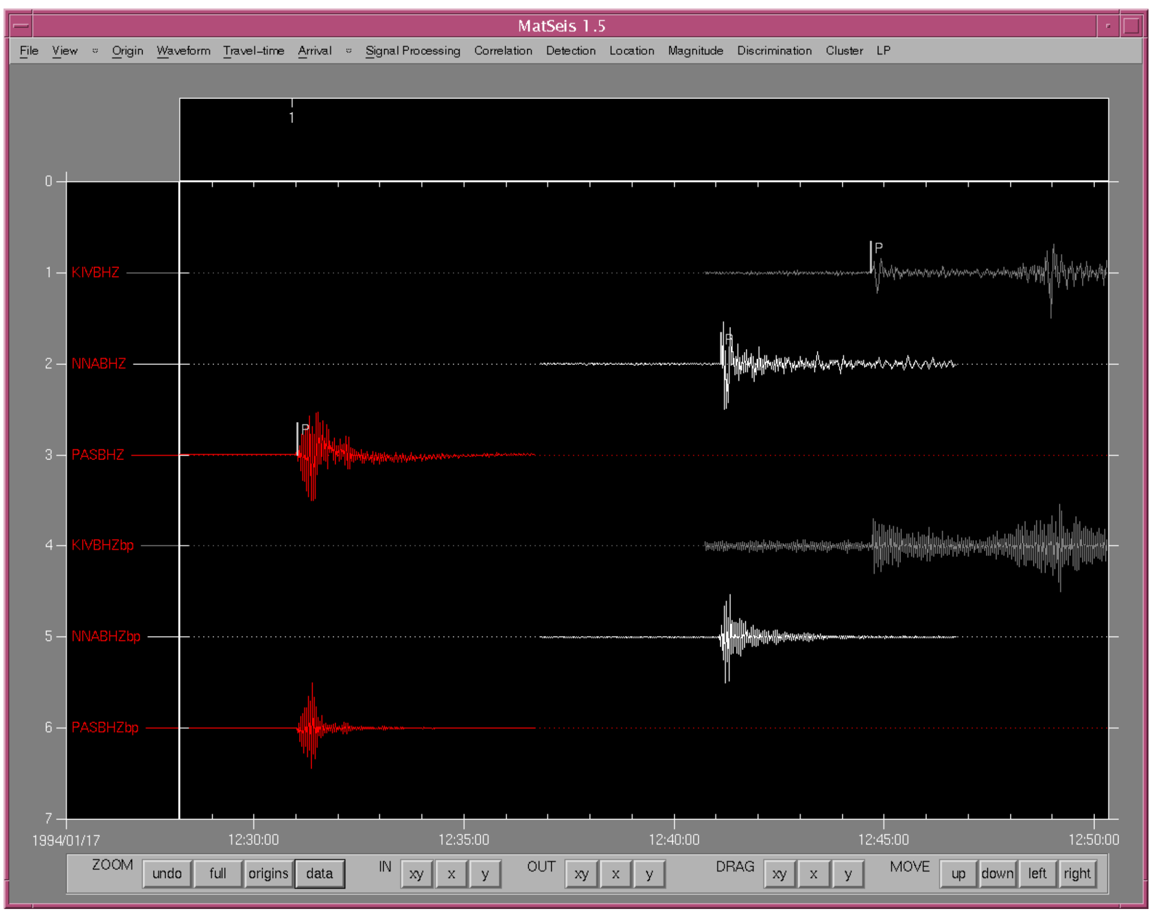
There are many ways to "separate" the waveforms. First, you can make them different colors so that differences can be seen where they are not similar. The simplest way to do this is to use the **Color** option of the **Wfm** pulldown and select **random**. Try this. Another method is to offset one of the waveforms when they are superimposed. Left-click on one of the NNA waveforms (or station/channel identifiers) to bring up the Station-Channel/Waveform Functions Pop-up, as discussed previously, and select **Edit** to bring up the Waveform Properties Window. One of the properties is **Offset**. This is a vertical offset in degrees. Try changing it to 5 and **Apply**. The superimposed waveforms will now be separated:



This method has provided the desired result and we would encourage the user to employ it where appropriate, but we generally avoid it because it has the disadvantage of having changed the distance at which the offset waveform is plotted to something that is no longer valid. This can lead to confusion subsequently if one decides, for example, to delete the raw waveform and work with the filtered version and forgets about the offset.

In some cases a better method is to take advantage of the mode of waveform display mode used by MatSeis when no origin is selected. Before we illustrate this, however, we need to get rid of the offset we added or it will adversely affect things. We could just add a negative offset to move the waveform back, but to be extra safe (and to make the reader practice a little more) instead you should delete all of the filtered waveforms using the **Delete** option of the **Waveform** pulldown (this will bring up a list of choices: select all stations, but only the BHZbp channel), and then recreate the filtered channels by using **Filter Design** again (all of the stations should still be selected). Note that the filter parameters do not have to be reset; the last values are retained. When you are done with this you should once again have 3 sets of 2 superimposed waveforms. Set the waveform colors to random to verify this.

Now we are ready to separate again. Begin by unselecting the origin (use any of the methods described previously). The travel time curves disappear because there is no origin to reference to, and the waveform sorting order for display is different because epicentral distance is not defined. The viewing reference frame is no longer well-suited to the data, so zooming is required. This can be done with the methods we used previously, or we can use the **data** zoom button (Zoom Buttons area), which automatically zooms to a window just big enough to show all of the data. Try this button. The display should now look something like this:



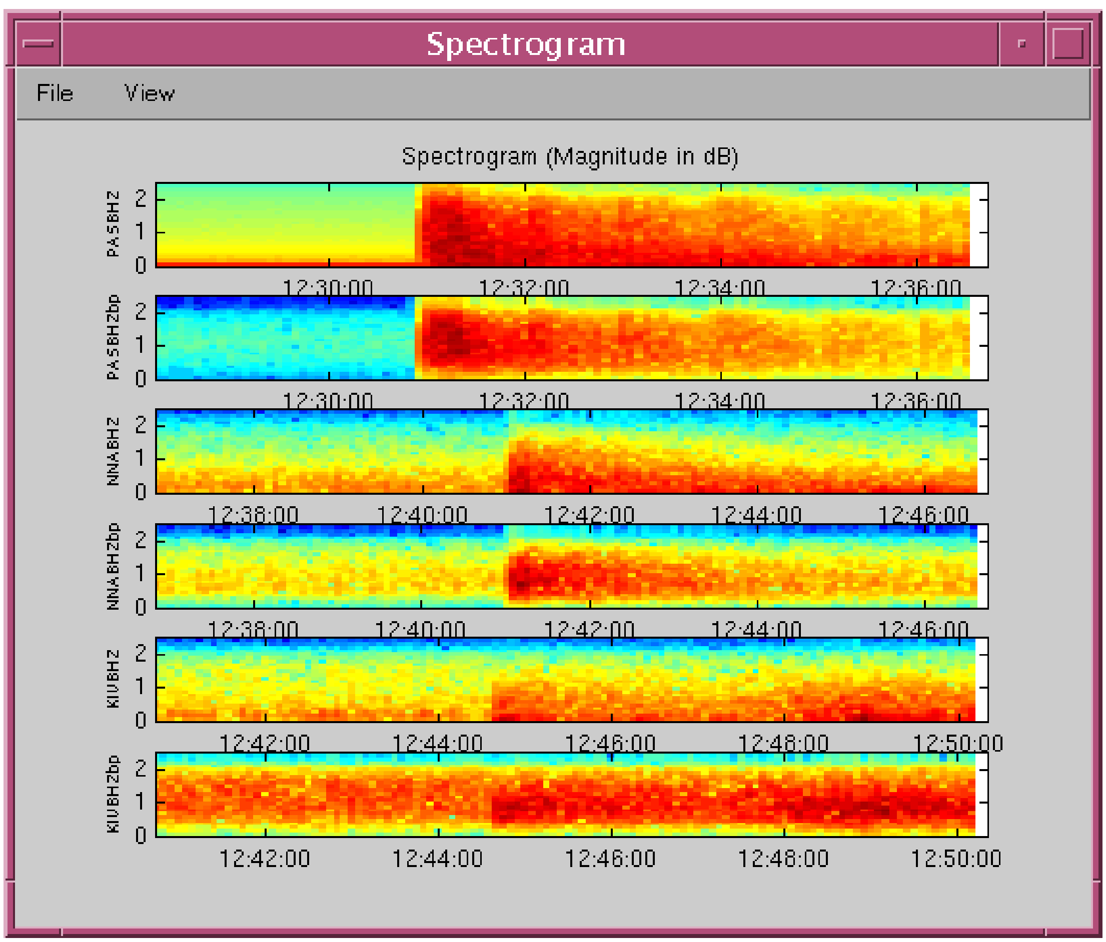
The grouping is first by type of processing (raw, filtered) and then alphabetically by station name within those groups. This type of display is particularly effective when comparing processing results for a suite of algorithms (e.g. a range of filter bands).

To get back to the origin-tied display mode, use the **undo** zoom button and then select the origin (you can use the **Select** option of the **Orig** pulldown if the origin is not visible). We have found this method of working back and forth between the display modes to be very useful in some situations. Please make sure that you have the origin selected again before proceeding. You can again use the **data** zoom button to automatically zoom to a nicely framed window once the origin has been selected.

A final way to separate overlain waveforms is to use **Free Plot**, as described previously. In this case, just select whichever group of waveforms you wish to separate using <ctrl-w> (you could select all three bunches in this case, or any of the individual bunches) and launch **Free Plot** using the **View** pulldown or <ctrl-f>. Try this.

Example 2: Spectrograms

The second example shows how to make spectrograms from selected waveforms. If the waveforms of interest are already selected (select the three raw waveforms, the three filtered waveforms, or all the waveforms if you like), and you have chosen the analysis windowing you want (in this case, the whole waveforms) all that is needed is to select the **Spectrogram** option of the **SigPro** pulldown. A pop-up will prompt you for **Low Frequency**, **Window Overlap**, and **Window Type**. Make your selections (the defaults are fine for our purposes) and select **Apply**. A window will appear with the spectrograms.



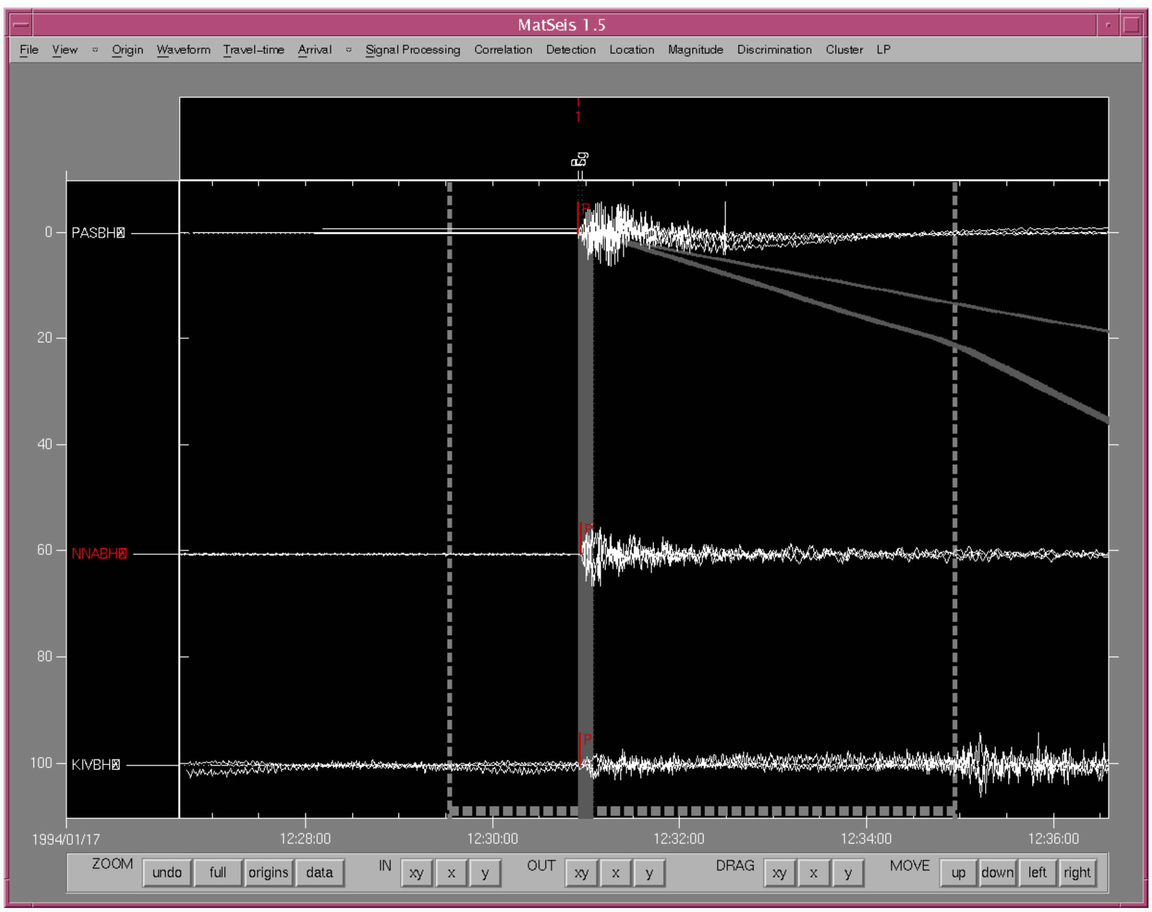
Use the **View** pulldown on this window to add a colorbar, change the colormap, or zoom.

Example 3: Three-Component Analysis

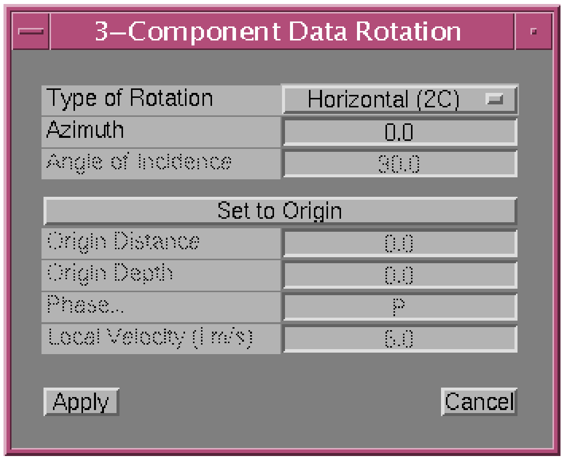
MatSeis includes several tools to aid in the analysis of three-component data. To illustrate we will need to add horizontal component data. Go ahead and delete the filtered waveforms from the previous section to keep the display from getting too cluttered. Use the **full** zoom button to set the window properly, then use the Waveform Read popup to read in the BHN and BHE channels for the stations previously read in. Be careful NOT to read in the BHZ channels again; if you do you will have multiple copies and this may lead to confusion. Make sure to choose the **Add** option in the Waveform Read popup rather than **Replace** or you will lose the BHZ channels already read. Once the horizontal channel data is read in, select the **undo** zoom button to get back to the zoomed view we had been working with.

Data Rotation

First, we will rotate the data. Select all three of the NNA channels using <ctrl-w> and the drag box. Next set a selection window around the P arrival using <ctrl-s> and the drag box. Your display should look something like this:

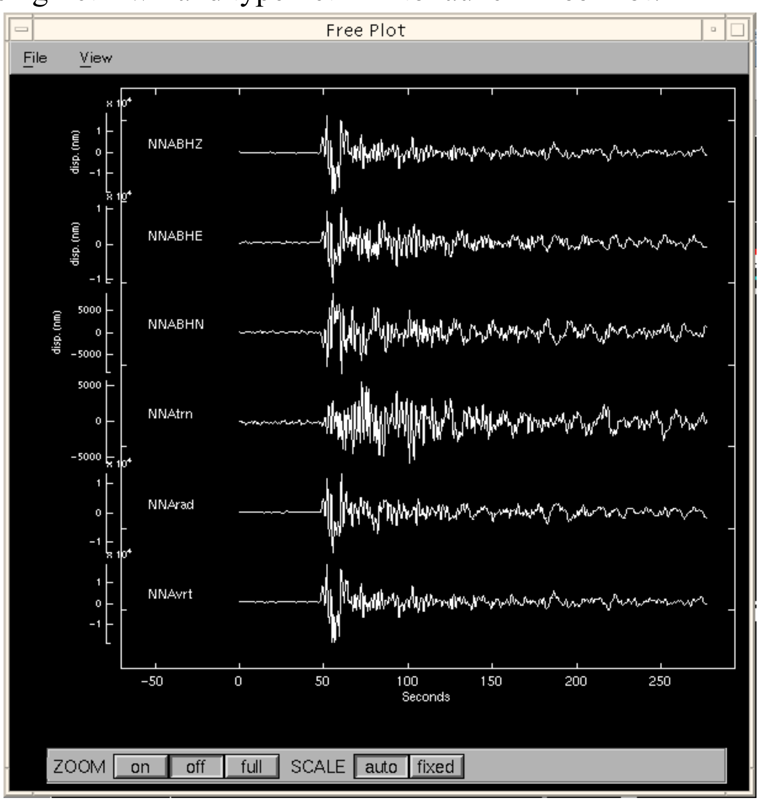


Now choose the **Three Component->Rotate** option on the **SigPro** pulldown. A popup will appear offering you various choices:



Type of Rotation allows you to choose to do a full rotation (i.e. include the vertical) or only rotate the horizontal components within the horizontal plane. Note that several of the options are only valid for the full rotation option and so will be grayed out for horizontal rotation. You can type in the directional information for the rotation by hand or point to the selected origin by choosing **Set to Origin**. For the tutorial, we will choose **Horizontal (2C)** and select **Set to Origin** to rotate to the current origin. Choose **Apply** when the proper selections have been made.

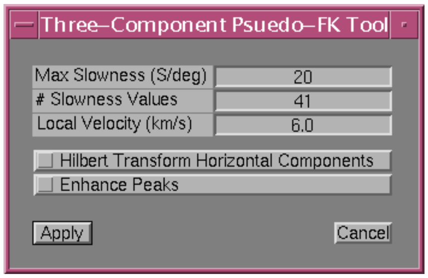
The rotated waveforms will now be available but they will be plotted at the same distance as the others and so will be difficult to see. To easily view them, we will use **Free Plot.**Select all of the NNA waveforms using <ctrl-w> and type <ctrl-f> to launch **Free Plot**.



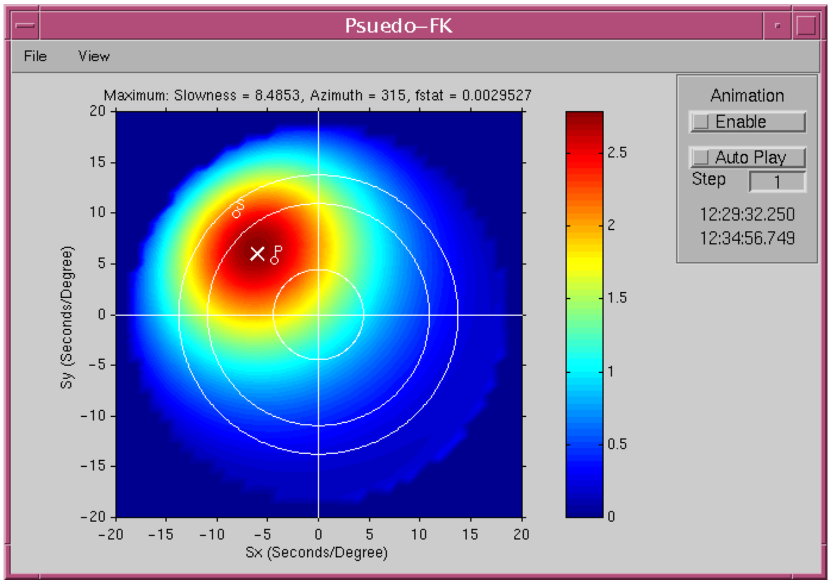
Polarization Analysis

Next we show a tool to quickly asses the polarization information. To keep things from getting too confusing, let's delete the rotate waveforms from within **Free Plot**. To do this, use <ctrl-w> within **Free Plot** to select them (i.e. the three ending in trn, rad, and vrt) -- note that they become selected in both **Free Plot** and the matseis **Waveform Window**, and use <ctrl-e> within the MatSeis **Waveform Window** to delete them. The waveforms are now deleted from MatSeis though they still appear in the **Free Plot** display. Dismiss/exit **Free Plot**.

Now we can proceed with the polarization analysis. Once again select the three raw channels for NNA, and using <ctrl-s> segment a small window (~10 seconds) centered around the P arrival. Note that the leading edge of the travel time curve is the true value for the IASP91 tables. Zoom in if you like to make it easier to set the window. Choose the **Three Component ->FK3C** option on the **SigPro** pulldown**.** We call this "FK3C" because the output looks like an FK (frequency-wave number) diagram for an array, but the processing is completely different: we show the power polarized in each direction as a ratio of the total power. If you have selected the sub-option correctly, a popup should appear:



Max Slowness controls the maximum slowness (and thereby angle of incidence) which will be plotted. **# Slowness Values** sets the slowness discretization. **Local Velocity** is used to convert slowness values to angles of incidence. **Hilbert Transform Horizontal Components** is useful for LR waves to equalize the phase difference between vertical and horizontal so that the power will appear to be linearly polarized. **Enhance Peaks** makes the peaks more evident in the plot. For the tutorial, we'll just use the default values, and select **Apply**.



As suggested above, this display should be interpreted just like an FK. The horizontal and vertical axes show the EW and NS wave numbers respectively. The thin white circles show the theoretical P slownesses for 5, 20, and 100 degrees distance for an event depth equal to the depth of the currently selected origin. The small white circles and accompanying labels the travel time curves currently in MatSeis: in this case P, S, and Lg) show the theoretical slowness and azimuth positions for these phases for the station being analyzed, in this case NNA. The center of the bull's-eye, marked with an "X" shows the direction of greatest polarization, which in this case should be near the P marker.

There is a control box in the upper right which allows the user to *animate* this display. To do this, select the **Enable** button. The FK-type plot will now be automatically updated whenever the segment window (indicated with the gray dashed lines) is changed. Try dragging the window along (you can grab the bottom, horizontal part of it by left clicking the mouse to do this) and watch how the display changes. If you have a slow computer, this could be painful. For better performance, and more precision, make the analysis window shorter. You can also automatically play through an arrival using the **Auto Play** button. To do this, first position the segment window well in front of the phase. Next type in the step value (this is in seconds). Try 5. Next select the **Auto Play** button (note that **Enable** must also be selected). You should now see the analysis window march along step by step and the display window update as it does. You can stop the calculation by pushing the **Auto Play** button again (it should now be unpressed). You must also deselect the **Enable** button to stop the automatic calculation before you leave this tool, otherwise MATLAB will accept no further commands from MatSeis!!!

This completes the tutorial. We encourage users to fully explore the pulldowns using Appendix A. In most cases, the user should be able to figure out how to use these tools on his/her own.

Section 5: Data Types

The Four Basic Data Types and Their Use

Matlab has four basic types of data: origins, waveforms, arrivals and travel times. A proper understanding of each of these is essential to fully take advantage of all that MatSeis has to offer.

For each of the data types, a general utility function is provided to query, edit, retrieve data from MatSeis into matlab.These functions are written in C code linked through the cmex interface, thus the data itself is stored in the C code, not in matlab. This is why you never see any of the MatSeis data when you type “who” or “whos” in matlab. In this section we will discuss each of these and provide examples of how to use them.

Origin

The origin data types holds all of the parameters associated with an event (origin time, lat, lon, depth, mb, etc.). The corresponding waveform function is simply “origin”.

We will provide an example to show how to access information for a particular origin for which we know the orid. Let this value be *our_orid*.

We first need to find the index corresponding to this orid (note that the index is *not* the same as the orid: orid is assigned when the data is placed in the database whereas index is the index assigned by MatSeis when the origin is read into memory). First get the indices of all origins:

```
>>origin_indices = origin(‘index’)
```

Next get the orids of all origins:

```
>>origin_orids = origin(‘orid’)
```

To find the index corresponding to *our_orid*, we can do this:

```
>>our_index = origin_indices(find(origin_orids == our_orid))
```

A more compact (if also more confusing) version that requires only one step would be:

```
>>our_index = find(origin(‘orid’) == our_orid)
```

Now we can get whatever information we want about our origin:

```
>>our_mb = origin(‘mb’,our_index);
>>our_locn = origin(‘location’,our_index)
```

Or we can select it or make it invisible:

```
>>origin('select',our_index);
>>origin('visible,our_index,0);
```

To see the full description of the origin function, type “help origin” at the matlab prompt.

Waveform

A MatSeis waveform is actually a combination of information corresponding to the waveform such as station and channel name and sample rate, as well as information corresponding to the station, such as location. The corresponding function is “waveform”.

Our first example will show how to extract into a matrix of column vectors the selected, windowed waveforms in matseis.

First, we find the indices of the selected waveforms:

```
>>waveform_indices = waveform('index','selected');
```

Next we use these indices to extract the windowed data:

```
>>waveform_data = waveform('data',waveform_indices,'segment');
```

waveform_data is an N x M matrix where N is the number of time points in each series and M is the number of series. Note the semicolon here. This is the standard matlab notation to keep from having the full matrix printed out to the screen. If you want to accomplish the whole thing in one command, you could use:

```
>>waveform_data = waveform('data','select','segment');
```

To plot one of the waveforms, you could try:

```
>>plot(waveform_data(:,1),'-r');
```

As a second example, we will show how to add a waveform to MatSeis (and display it in the Waveform Window). Suppose that our data is in a matlab array called our_data and that it has various parameters in the variables our_parametername. Here is what we do:

```
>>new_index = waveform('create');
>>waveform ( 'data', new_index, our_data );
>>waveform ( 'samprate', new_index, our_samprate );
>>waveform ( 'time', new_index, our_start_time );
>>waveform ( 'length', new_index, lenth(our_data) );
>>waveform ( 'station', new_index, our_station_name );
>>waveform ( 'channel', new_index,our_channel_name);
>>waveform ( 'location', new, [our_lat our_lon our_elevation]);
```

That creates a new waveform and gets an index for it and then assigns the various properties associated with the index. Now any action to redraw the screen should show the new waveform, e.g.

```
>>ms_draw;
```

To see the full description of the waveform function, type “help waveform” at the matlab prompt.

Arrival

The arrival data type is just what you expect. It provides all of the information about an arrival (e.g. time, station & channel, arrival ID) and also its association information (which origin it is associated with, if any). The corresponding function is “arrival”.

In our example, we will show how to fetch the indices for the arrivals associated with our origin with orid our_orid and then how to use these to change the properties of the arrivals.

First, we get the indices for the associated arrivals:

```
>>arrival_indices = find(arrival(‘origin’) == our_orid)
```

To get the arids for these arrivals:

```
>>arrival_arids = arrival(‘arid’,arrival_indices)
```

To select them, first deselect everything:

```
>>arrival(‘select’,arrival(‘index’),zeros(size(arrival(‘index’),1),1))
```

Then select the associated arrivals

```
>>arrival(‘select,arrival_indices,ones(size(arrival_indices,1),1))
```

To see the full description of the arrival function, type “help arrival” at the matlab prompt.

Travel Time

The travel time data type is probably the least familiar, but we highly recommend learning to use it as it is essential for many types of data processing. It contains all of the information associated with the travel time curves for a particular phase (slowness, time, alignment). The corresponding function is “travtime”.

In our example, we show how to align the display on the PcP travel time curve.

First, we find the index of the PcP curve:

```
>>travtime_index = travtime(‘index’,’PcP’)
```

we then align:

```
>>travtime(‘current’,travtime_index);
```

As a second example, we show how to find the theoretical time and slowness for the P phase at distance our_dist for the current origin:

```
>>our_time = travtime(‘time’, ‘P’, [origin(‘depth’,’current’) our_dist])
```

```
>>our_slow = travtime('slowness', 'P', [origin('depth','current') our_dist])
```

To see the full description of the arrival function, type “help arrival” at the matlab prompt.

What Next?

These four functions when combined with the basic functions offered by matlab and its various toolkits should allow the user to develop virtually any type of functionality for seismic data. For examples, the reader should refer to the numerous m-files in the MatSeis delivery. With these, you have an abundance of examples to build upon and with a little effort you should soon be able to build a variety of useful functionality of your own. Remember that because matlab is an interpreted language, you can essentially prototype at the command line, trying each new line of code as you add it in.

Section 6: Summary

While we realize that the user has seen only a relatively small portion of the functionality of the software, he/she should have a good understanding of the basics. The software was designed to be self-explanatory and easy to learn. Many of the types of operations and pop-up menus (Read, Write, Show, Delete) are essentially the same for all 4 types of data, so once usage is learned for one, the others should quickly follow.

The best way to learn MatSeis is to use it. Read in a test data set and try things. Setup your own configuration file to learn how it is used. In fact, we recommend setting up configuration files for each data set/application. Examine database files before, during, and after reads and writes to see what is happening to them. Setup a travel-time table for your favorite phase. Examine the numerous m-files in the MatSeis directory and figure out how they work. Borrow liberally from them to form functions of your own (and send them to us if they seem useful for others!).

We feel confident that if the user is willing to invest a relatively small amount of time in learning the system and (especially) the data formats, he/she will be well-rewarded.

Appendix A: Pulldowns

The complete listing of all of the pulldowns is given below.

File

The options in File are used to setup, restart, end, and print pictures of a MatSeis session.

- **Reconfigure** - reconfigures to the startup configuration by reading the configuration file (if used).
- **Input Database Setup** - sets database type and parameters.
- **Output Database Setup** - sets database type and parameters. Currently, only flatfile is allowed.
- **Print** - sets the print options and print to a file or printer. Note that this tool can be used to print *ANY* MatSeis tool (choose which figure you want to print from the popupmenu in the tool).
- **Close All Pop-ups** - closes all popups associated with MatSeis. This is very handy if you have an error in a GUI such that the figure has become invisible but is still around. Finding the handle to the invisibile object so you can delete it can be a pain: if you think you have such a situation just use this option.
- **Restart** - restarts MatSeis.
- **Exit** - quits MatSeis.

View

The options in View are used to control the waveform window.

- **Properties** - pops up a GUI allowing the user to set various parameters controlling the display.
- **Resize Axes** - adds resize handles to the axes so that individual portions of the display can be resized.
- **Zoom** - access a full sub-menu of zoom choices

  -> *Undo* - undo last zoom operation.

-> *Full* - zoom to window big enough to show all visible travel time curves for selected origin.

-> *Origins* - zoom to window big enough to show all visible origins.

-> *Data* - zoom to window big enough to show all visible data.

-> *Refresh* - redraw current view.

-> *In* - provide cursor for drag-box zooming in.

-> Out - automatically unzoom by 150%.

-> *Drag* - provide cursor for drag-box dragging to re-center the view.

-> *Move* - automatically re-center the display by moving half a screen in a given direction.

- **Set Axes** - set the limits of the plot along the x-axis (time) and along the y-axis (distance).
- **Time Alignment** - there are three options in Time Alignment that are used to change how the waveforms and phase curves are plotted.

-> *Phase* - chooses a phase on which to align the waveforms. The phase to be aligned can also be changed by double-clicking on a phase in the graphics window or choosing align from the waveform pop-up menu.

-> *Reduction Velocity* - applies a reduction velocity in seconds per degree.

-> *Reset* - resets to no alignment. This can also be done by double-clicking the phase on which the display is aligned.

- **Map Tool** - Bring up the map tool with the origins and stations currently visible in matseis.
- **Alpha List** - Bring up a tool for displaying and manipulating the arrivals for any origin.
- **Measure Tool** - Bring up a tool for detailed measurements of arrival times and various associated amplitudes.
- **Free Plot** - send selected, windowed waveforms to separate, non-epicentral-distance controlled display. Waveforms in this display can be moved by left-clicking with the mouse.
- **Screen Capture** - make a quick-and-dirty plot of the main waveform window in its current state. This can be handy if you want to compare say a waveform plot of one origin with that of another.

Orig

The options in Origare used to read, write, select, delete, and display origin data. In addition we provide additional options to facilitate moving between several different origins (**Current Origin**, **Next Origin**).

- **Read** - reads origins from the input database to display in MatSeis. To get a list of origins in the database, choose a start and end time and click on the "Update" button. An easy way to get the start and end times is to click on "Set Time to Axes". A list of all the origins in that time span will be displayed. The origins can be sorted by time, latitude, longitude, depth and magnitude. Pick the origins you want to display in the graphics window by selecting them individually or clicking on "Select All". To read all of the arrivals associated with a given origin, choose the "Read Arrivals" option.
- **Write** - writes origins to the output database (new orids are generated using the lastid table). Selection is from a sortable list of all origins currently in memory, similar to the read list.
- **Show** - shows selected origin(s) from those in memory. This option allows the user to display in the graphics window only the origins of interest without losing information that has been read into MatSeis (as happens with Delete). Selection is from a sortable list similar to the read list. Origins can be "unshown" (but not deleted!) by clicking on an origin in the graphics window and choosing erase from the pop-up menu.
- **Delete** - deletes some or all of the origins picked in Read. Origins can also be deleted by clicking on an origin in the graphics window and choosing delete from the pop-up menu.
- **Select** - picks the origin used for various operations (e.g. time and distance alignment). Only one origin can be selected at a time. Selection is from a non-sortable list. Origins can also be selected by double-clicking on an origin in the graphics window or choosing select from the origin pop-up menu.
- **New** - creates a new origin. Origin information (e.g. location) can be edited by clicking on the origin in the graphics window and choosing edit from the pop-up menu.
- **Current Origin** - read in data for the current origin assuming the same stations and channels. This is useful for network operators reviewing a series of events.
- **Next Origin** - read in data for next origin (in time) assuming the same stations and channels. This is useful for network operators reviewing a series of events.

Wfm

The fourteen options in Waveform are used to read, write, select, delete, and display waveform information.

- **Read** - selects network, station and channel information of the waveforms to be plotted. Choose a network to get a list of stations and channels. The start time and duration will set the limits on how much of the waveform is plotted. These values can be entered manually or set by choosing “Set Time to Axes”. Note that MatSeis can be slowed down considerably if too much data is requested. Each station has distance and azimuth information that corresponds to the selected origin. Stations can be sorted by distance or azimuth. Pick the stations from which you want to display waveforms by selecting individually or clicking on “Select All”. One or more channels must also be selected. Other options to choose are to add or replace waveforms, ask for station locations only (useful for View --> Map option), demean the waveforms, or zoom to data.

- **Show** - shows only selected waveform(s) without deleting the other waveforms picked in Read. Works like Show for Origin. Waveforms can be erased by clicking on a waveform in the graphics window and choosing erase from the pop-up menu.

- **Delete** - deletes some or all of the waveforms picked in Read. Selection is from a sortable list similar to the read list. Choose either specific waveforms or specific station and channel information to delete.Waveforms can also be deleted by clicking on a waveform in the graphics window and choosing delete from the waveform pop-up menu.

- **Select** - selects waveforms on which to do the signal processing. Selection is from a sortable list similar to the read list. Waveforms can also be selected by double-clicking on a waveform in the graphics window or by choosing select from the waveform pop-up menu.

- **Properties** - pops up a GUI to allow editing of waveform display parameters (e.g. color, amp) and channel name. The channel name option can be used to change the name for copied and filtered data for clarification.

- **Time Resolution** - controls the resolution at which waveform is plotted (increase for better resolution).

- **Distance Resolution** - controls rounding of epicentral distance for plotting (e.g. set to 0 for no rounding; set to 1 to round to the nearest degree).

- **Display** - two options:

  -> *Waveforms* - turns waveform plotting on or off

  -> *Baselines* - turns waveform baseline plotting on or off.

- **Scaling** - four options to change the scaling of the waveforms:

  -> Global Fixed - relative scaling to the largest amplitude of any waveform on or off the screen.

  -> Global Automatic - automatically scales to equalize maximum zero to peak (or trough) on or off the screen for each waveform.

  -> On-screen Fixed - same as Global Fixed, but only considers portion of waveforms shown on screen.

-> On-screen Automatic - same as Global Automatic, but only considers portion of waveforms shown on screen.

- **Amp** - changes the amplitude of all the waveforms via a pop-up with presets. The amplitude of a particular waveform can be changed by clicking on the waveform in the graphics window and choosing amp from the waveform pop-up menu.
- **Offset** - changes the offset (vertical, in degrees) of all waveforms via a pop-up with presets. The offset of a particular waveform can be changed by clicking on the waveform in the graphics window and choosing offset from the waveform pop-up menu.
- **Clip** - sets a normalized amplitude value above which all the waveforms will be clipped. Useful for preventing high amplitude portions of certain waveforms from dominating the display. To clip a particular waveform click on the waveform in the graphics window and choose clip from the waveform pop-up menu.
- **Color** - assigns colors to all the waveforms. The default is white. If random is chosen than all waveforms will be assigned a random color. The color of a particular waveform can be changed by clicking on the waveform in the graphics window and choosing color from the waveform pop-up menu.
- **Line Style** - changes the appearance of the lines (solid, dot, dash, dotdash, various symbol types) used to plot all the waveforms. The symbols are useful for examining at an individual digitization point level. The line style of a particular waveform can be changed by clicking on the waveform in the graphics window, choosing edit from the waveform pop-up menu, and selecting a style from the subsequent pop-up.
- **Line Width** - changes the width of the lines used to plot all the waveforms. The line width of a particular waveform can be changed by clicking on the waveform in the graphics window, choosing edit from the waveform pop-up menu, and selecting a width from the subsequent pop-up
- **Reset** -returns all the waveform plotting parameters to the original values.

TT

The options in Travel-time are used to read and display travel-time curve information.

- **Read** - picks selected phases from user definable data files of travel-time information that are plotted against the selected origin. Three different formats are available. Choose the format and specify the location of the files first. Then specify a phase list file to get a list of phases to pick from (this controls the size of the list). Pick the phases you want from the list by clicking individually or clicking “Select All”.
- **Write** - write out travel-time tables.
- **Show** - shows only selected phase curve(s) without deleting the other phase curves picked in Read. This option allows the user to display in the graphics window only the phases of interest without losing information that has been read into MatSeis (as hap-

pens with Delete). Phases can also be picked not to be shown by clicking on a phase in the graphics window and choosing erase from the pop-up menu.

- **Delete** - deletes some or all of the phase curves in memory. Phases can also be deleted by clicking on a phase in the waveform window and choosing delete from the pop-up menu
- **Select** - select a travel time curves from a pop-up list. Curves can also be selected by double-clicking on a curve in the graphics window.
- **Display** - two options:

  -> *patches* - turns travel time curve plotting on or off

  -> *Baselines* - turns travel time curve baseline plotting on or off.
- **Width** - pops up a GUI allowing the user to change the width of the travel time curves.
- **Colors** - assigns colors to all the phase curves. The default is gray. If random is chosen than all phase curves will be assigned a random color. The color of a particular phase can be changed by clicking on the phase in the graphics window and choosing color from the pop-up menu.

Arr

The options in Arrival are used to read, write, select, delete, and display arrival information.

- **Read** - reads arrivals from the database to display in the graphics window. To get a list of arrivals in the database, choose a start and end time and click on the “Update” button. An easy way to get the start and end times is to click on “Set Time to Axes”. A list of all the arrivals in that time span will be displayed. The arrivals can be sorted by arid, orid, station, channel, phase, or time. Pick the arrivals you want to display in the graphics window by selecting them individually or clicking on “Select All”. *Note: you can also read in all of the arrivals associated with a given event by choosing the “Read Arrivals” option in the Read option of the Origin pulldown*.
- **Write** - writes arrivals to the database (new arids are generated using the lastid table). Selection is from a sortable list of all arrivals currently in memory, similar to the read list.
- **Show** - shows selected arrival(s) from those in memory. This option allows the user to display in the graphics window only the arrivals of interest without losing information that has been read into MatSeis (as happens with Delete). Selection is from a sortable list similar to the read list. Arrivals can be “unshown” (but not deleted!) by clicking on an arrival in the graphics window and choosing erase from the pop-up menu.
- **Delete** - deletes some or all of the arrivals in memory. Arrivals can also be deleted by clicking on an arrival in the graphics window and choosing delete from the pop-up menu.

- **Associate** - pops up a GUI with lists of the arrivals and origins to allow the user to form/change associations.
- **Default Phase** - sets the default phase name used when picking arrivals. Phase names can be changed by clicking on the arrival in the waveform window and selecting the edit option from the pop-up, but when picking many of the same phase at once (e.g. P) it is much quicker to set the default type first.
- **Pick Travel-times** - automatically makes a pick for every shown phase for every shown waveform at the theoretical arrival time. Useful for generating test/demo data sets.

SigPro

The options in Signal Processing are used to set up and run signal processing algorithms.

- **Options** - chooses to replace waveforms or create new ones. If new ones are created they will be plotted at the same epicentral distance as the originals in the event-tied display mode. New waveforms will have a suffix added to the original name dependent on the type of processing.
- **Time Segment** - picks the time interval over which the signal processing will be done. Either the whole waveform or a time segment can be chosen. A time segment can be selected by setting start time and duration, by setting the time to axes, or by using a box to define the time segment on the graphics display.
- **Filters** - designs and implements different filters. The time segment over which the filter is applied is defined in Time Segment.

  -> *Design* - pops up a GUI which lets the user design a filter by choosing filter type, band type, cutoff frequency and order. The user can also plot the frequency response, impulse response and poles of this filter.

  -> *STA/LTA* - lets the user set the parameters for a STA/LTA detector (average type, width and delay) and plot the step response and window placement.

  -> *Prediction Error* - lets the user set the parameters for a LMS adaptive prediction error.

- **Operations** - applies arithmetic operations to the selected waveform(s). The time segment over which the operations are applied is defined in Time Segment.

  -> *Custom Function* - allows the user to apply a custom function to a selected waveform and specify the name for the new channel which will be created.

  -> *Absolute Value* - calculate waveform absolute values

  -> *Add DC Offse*t - add a dc offset to the waveform

  -> *Apply Gain* - apply a gain as set by the user to the waveform

-> *Clip* - lets the user set a clip threshold and set clip type to be above or below the threshold. Unlike the “Clip” option in the Waveform pulldown, this function will actually clip the data rather than just show it as clipped.

-> *Negate* - changes the polarity of the waveform

-> *Sign* - calculate sign (plus or minus 1) of waveform

-> *Square* - squares waveform

-> *Square Root* - calculate square root of waveform

-> *Hilbert Envelope* - apply Hilbert transform to waveform

-> *Power* - apply a power as set by the user to waveform

-> *Demean* - remove mean value from waveform

-> *Detrend* - remove a linear trend from waveform

-> *Difference* - calculate sample-to-sample difference for waveform

-> *Derivative* - differentiate waveform

-> *Downsample* - downsample the waveform by a factor set by the user

-> *Integral* - integrate waveform

-> *Window* - lets the user choose a window type to multiply the data with. The frequency response of the window can be plotted.

- **Time Functions** - applies different timing functions to the selected waveform(s).

-> *Cut Time Segment* - lets the user cut out a specific time segment. Time Segment must be on.

-> *Time Shift* - lets the user time shift the selected waveform(s) by a specific number of seconds.

-> *Resample* - lets the user resample the waveform to a new sample rate.

- **Multi-Waveform** - performs operations that combine two or more waveforms. The waveforms that are produced are called SUM, PROD or stachan#. They are plotted at a distance that is an average of the distances of the stations that are combined.

-> *Sum Waveforms* - sums two or more waveforms

-> *Multiply Waveforms* - calculate product of two or more waveforms

-> *Concatenate Waveforms* - concatenate two or more waveforms in tim

- **Three-Component** - perform three-component processing

-> *Rotate* - rotate the data to form rotated components. Rotation can either be in horizontal plane only, or full.

-> *FK3C* - creates an FK-like display of linearized power vs. total power; useful for verifying arrivals.

-> *Data Synthesis* - form synthetic three-component data for testing purposes. Amplitudes on each component will be for selected origin and specified phase.

- **Array** - performs array processing.

-> *Beam* - forms standard time delay beams for array data (if site, sitechan, and affiliation are setup correctly). A pop-up menu will allow the user to specify azimuth as a single value or range of values (e.g. 0:15:360 means 0 to 360 every 15 degrees), Slowness as a single value or set of values, or you can use “Set to Origin” to form origin beams for all phases (travel-time curves) shown. Output is either a set of standard beams (Beam Set), a set of beam powers (Beam Set Power, this is the squared output), or a single beam which is the maximum beam power on any beam in the set at each time point (Max Beam Power).

-> *FK* - pops up a GUI controlling the creation of an FK for the windowed data for the selected array channels. The user can specify slowness parameters, frequency band, window type, and plotting options.

-> *Fast FK* - pops up a GUI controlling the creation of a Fast FK for the windowed data for the selected array channels. The user can specify slowness parameters, frequency band, window type, and plotting options.

-> *Vespagram* - pops up a GUI controlling the creation of a vespagram for the window data for the selected array channels. A vespagram is a plot of slowness vs. time (azimuth is constant). The user can specify the slowness parameters, time discretization, and a clipping factor.

-> *Spatial Coherence* - produces a single output stream for multi-channel/multi-station data using Greg Wagner’s spatial coherence algorithm (principal eigenvalues from decomposition in the frequency domain). A pop-up will show the number of channels selected and prompt the user for window size (in points), and window overlap (%), as well as whether glitch elimination (based on contribution to the trace of the covariance matrix) should be used.

-> *Data Synthesis* - form synthetic array data for testing purposes. Delays will be for selected origin and specified phase.

-> *Array Response* - calculates FK array response.

- **Transfer Tool** - lets the user deconvolve and/or convolve instrument responses for a selected waveform and send resultant waveform back to MatSeis. Current version can read both CSS format instrument response files as well as SEED format instrument response files.

- **Power Spectral Density** - lets the user choose the overlap and window type and computes power spectral density(s) for the selected waveform(s) and plots them in a second window. This window can be printed.
- **Spectrogram** - lets the user choose the overlap and window type and computes spectrogram(s) for the selected waveform(s) and plots them in a second window. Color bars are also plotted. This window can be printed.
- **Cepstrum** - lets the user choose the FFT length and window type and computes cepstrum for the selected waveform and plots them in a second window. This window can be printed.

Corr

The options in Correlation are used to perform various correlations of waveforms.

- **Waveform Correlation Tool** - pops up a tool facilitating comparison of two selected waveforms. Select two waveforms and set a processing window using <ctrl-s>, then launch the tool. The interactive display will show the superimposed waveforms and the cross-correlation stream.
- **Multi-waveform Correlation** - forms a correlation table for all selected waveforms (2 or more). Select two or more waveforms and set a processing window using <ctrl-s>, then launch the tool. A n x n table will popup (n is the number of selected waveforms) showing the maximum correlation values (normalized by the auto correlations) for each pair. Note that the diagonals (waveforms with themselves) are 1 by definition.

Detn

The options in Detection are used either to process waveforms to facilitate detection or to actually created detections.

- **STA/LTA** - lets the user set the parameters for a STA/LTA detector (average type, width and delay), plot the step response and window placement, and apply it to the selected, windowed data. Select one or more waveforms (and set a processing window using <ctrl-s> if you like) and launch the tool. The GUI allows you to design and STA/LTA type filter to apply to the waveforms. Once you have the parameters set, select **Apply** to create the new waveforms, which will have “S/L” appended to the channel names.
- **Trigger Tool** - brings up a popup to allow the user to design a trigger to create detections (arrials) for selected windowed streams. Typically, this would be used on waveforms created by **STA/LTA**. Launch the tool and a GUI will appear with various parameters to set to control the triggering and name of the arrivals that will be added. When you are satisfied with the settings select **Apply** and the arrivals will be added to the selected waveform in the MatSeis Waveform Window.

Locn

The options here are used for event location

- **Locator Tool** - popup GUI to set parameters and display output of event locator for current origin. This tool is discussed in the tutorial.
- **Arrival Order Tool** - popup GUI to locate origin solely based on the order of the arrival times, without using the travel-time tables. You will need a selected origin and associated arrivals. Launch the tool and you will get a GUI allowing you to choose the origin you want to select (you can choose a different one) and which of the phases you want to use, as well as the lat. and lon extent and increments of the Earth you want to search for the location. When you have things set as you want, choose **Apply** to see the resultant map. The more stations and more arrivals you have the sharper the location will become.
- **Depth Phase Tool** - popup GUI to find pP phases in seismic data using phase shift deconvolution, simple deconvolution and autocorrelation This tool tries to find pP by deconvolving direct P out of a set of waveforms and then stacking the waveforms to enhance the pP arrival. You will need a selected origin and selected associated waveforms, and you must have P and pP (and only these) travel time curves in MatSeis. For the stacking, the tool will align on either the theoretical P or picked P.

Mag

The options here are used for calculating magnitudes

- **Magnitude Tool -** popup GUI to calculate the network magnitude for the specified arrivals of an origin. This tool is described in the tutorial.
- **CodaMag Tool -** popup GUI to calculate the coda magnitude. This tool has not yet been made available as part of the MatSeis release (selecting the option will results in an error).

Dscrm

The options here are used for discriminating event types.

- **Phase Ratio Discrim Tool -** popup GUI to calculate P/Lg amplitude ratios. This tool has not yet been made available as part of the MatSeis release (selecting the option will results in an error).
- **Surfview Tool** - popup GUI to send surface wave group velocity surfaces to the map. This tool has not yet been made available as part of the MatSeis release (selecting the option will results in an error).

Clust

This pulldown contains various tools for applying cluster analysis to events.

- **Dendrogram -** popup GUI to compute dendrograms. Classify origins by the similarity of their waveforms for a selected station, channel, and phase. This tool allows you to build a dendrogram for a set of waveforms for two or more events for a given station (or small set of stations). To use it, you will need to have a set of origins in MatSeis and the associated waveforms for at least one common station. Reading the waveforms in can be simplified using the next tool, **Read Event Data**. **Dendrogram** is complex and will in the future have its own User's Manual.
- **Read Event Data** - popup GUI to read in waveform data for a set of origins; designed specifically for use with Dendrogram This tool is provided specifically to help read in data for **Dendro Tool**, though it could be used for other purposes. The tool assumes that you already have a set of origins in MatSeis but have not yet read in the waveforms. Launch the tool and you will get a GUI providing you with lists of origins, stations, and channels. Select the origins you want to read waveforms for, and the station(s) and channel(s) you want to read. You will also set the lead and duration times (relative to origin time) for the waveform segments, and you can down sample them as they are read in if you like (**Dendro Tool** does lots of waveform correlations and so will run faster for lower sample rates if you can afford the potential loss of information). When all is set, select **Apply** and the waveforms will be read in. You can then invoke **Dendro Tool**.

LP

This pulldown contains tools for analysis of surface wave data.

- **PhaseMatch Tool -** popup GUI to apply phase match filter analysis to a selected waveform. This tool has not yet been made available as part of the MatSeis release (selecting the option will results in an error).

- **Surfview Tool -** popup GUI for loading and sending surface wave group velocity surfaces to **Map Tool**. This tool has not yet been made available as part of the MatSeis release (selecting the option will results in an error).

Infra

This pulldown contains tools for analysis of infrasound data.

- **Infra Tool -** popup GUI to process infrasound array data to determine portions of high correlation and to derive velocity and azimuth information which can be sent to the **Map Tool** to locate events. This tool has not yet been made available as part of the MatSeis release (selecting the option will results in an error).

Appendix B: Data Pop-ups

There are four types of data objects in MatSeis and each has a pop-up menu or a series of pop-up menus which can be accessed by clicking on the data object. These pop-ups allow the user to review/edit various properties of the object and perform various functions on it. The pop-ups for each of the four types are shown below.

bold = function; *italics* = property

Origin

- *origin ID* - unique ID # for each origin
- **select/unselect** - for origin operations
- **edit** - pop-up menu of editable origin properties
  - *origin ID*
  - *time (origin)*
  - *latitude*
  - *longitude*
  - *depth*
  - *mb*
  - *ms*
  - *ml*
- **raise** - move in front of other overlapping origins
- **lower** - move behind overlapping origins
- **erase** - remove origin from display but not from memory
- **delete** - remove origin from display and from memory
- **<cancel>** - exit pop-up

Waveform

- *station name*
- **select/unselect** - for waveform operations
- **amp** - of displayed waveform
- **color** - of displayed waveform
- **edit** - pop-up menu of editable waveform and station properties
  - *station*
  - channel
  - *start time* - of displayed waveform
  - *latitude* - of station
  - *longitude* - of station

- *elevation* - of station
- *amplitude* - of displayed waveform
- *offset* - vertical offset of displayed waveform
- *clip level* - of displayed waveform
- *color* - of displayed waveform
- *line style* - of displayed waveform
- *line width* - of displayed waveform

- **add arrival** - add an arrival with the default phase name at the point where you left-clicked to access the pop-up
- **raise** - move in front of other overlapping waveforms
- **lower** - move behind overlapping waveforms
- **erase** - remove waveform from display but not from memory
- **delete** - remove waveform from display and from memory
- **<cancel>** - exit pop-up

Travel-time

- *phase name*
- **align/unalign** - align display on travel-time curve
- **color** - of displayed travel-time curve
- **width** - of displayed travel-time curve
- **slowness** - display the slowness at the point on the travel-time curve where you left-clicked to access the pop-up
- **raise** - move travel-time curve in front of other overlapping curves
- **lower** - move travel-time curve behind overlapping curves
- **erase** - remove travel-time curve from display but not from memory
- **delete** - remove travel-time curve from display and from memory
- **<cancel>** - exit pop-up

Arrival

- *arrival ID* - unique ID # for each arrival
- **associate/unassociate** - associate/unassociate the phase with the an origin. Origin must be selected to associate.
- **phase** - of the arrival
- **move** - retime arrival. Cross cursor will appear and time will be displayed next to phase name. Left-click to choose new time.
- **edit** - pop-up menu of editable arrival and station properties
    - *arrival ID*
    - *origin ID*
    - *station*
    - *channel*
    - *phase*
    - *time*
    - *standard deviation* - picking accuracy of phase (= deltim from arrival table)
    - *residual* = observed time minus predicted time
    - *location defining* - T/F: was this pick used to locate the event?

- **raise** - move arrival in front of overlapping arrivals
- **lower** - move arrival behind overlapping arrivals
- **erase** - remove arrival from display but not from memory
- **delete** - remove arrival from display and from memory
- **<cancel>** - exit pop-up

Appendix C: Buttons

At the bottom of the MatSeis display are five groups of button used for zooming and translating the reference frame. Each of these is described below.

ZOOM

- **Undo** - sequentially “undo” any operations using ZOOM, IN, OUT, DRAG or MOVE.
- **Full** - return to the full window.
- **Origins** - replot the graphics window around the origins that have been read in.
- **Data** - replot the graphics window around the data that has been read in. Typically used when no origin is selected. This feature is also valuable when adding or multiplying waveforms.

IN

- **XY** - pick a box in xy space which changes the limits of both x and y that are displayed in the graphics window.
- **X** - pick a line in x space which changes the limits of x that is displayed in the graphics window.
- **Y** - pick a line in y space which changes the limits of y that is displayed in the graphics window.

OUT

- **XY** - enlarge the graphics window to 200% (X2) of the current limits in both the x and y direction.
- **X** - enlarge the graphics window to 200% (X2) of the current limits in the x direction.
- **Y** - enlarge the graphics window to 200% (X2) of the current limits in the y direction.

DRAG

- **XY** - draw a box in xy space whose corners define the old and new position of a data point, i.e. you “drag” a feature to where you want it to be displayed.

- **X** - pick a line in x space to define the drag.
- **Y** - pick a line in y space to define the drag.

MOVE

- **Up** - move the graphics window up by an amount equal to 1/2 of the total of the y axis.
- **Down** - move the graphics window down by an amount equal to 1/2 of the total of the y axis.
- **Left** - move the graphics window to the left by an amount equal to 1/2 of the total of the x axis.
- **Right** - graphics window to the right by an amount equal to 1/2 of the total of the x axis.

Appendix D:
MatSeis Environmental Variables

A huge number of the settings in MatSeis are controlled by UNIX environmental variables which can be set in the matseis startup script (e.g. run_matseis) as well as in the configuration (config) files. Using these properly, a user can design a config file which will have MatSeis start up with virutally everything set properly to begin analysis.

MS_ORID	A comma separated list of orids. If this list is set in the config file, then these orids will automatically be read in at startup.
MS_STA	A comma separated list of stations. If this list is set in the config file, then the corresponding waveforms (formed by combination with MS_CHAN) will automatically be read in for the first orid in the MS_ORID list.
MS_CHAN	A comma separated list of channels. As above for MS_STA.
MS_PHASE	A comma separated list of phase names. If this list is set in the config file, then the corresponding travel time curves will be read in at startup (assuming the corresponding tables exist).
MS_TIME	A comma separated two element vector specifiying the start time and duration of the MatSeis Waveform Window. If specified in the config file, MatSeis will automatically zoom to this time window at startup.
MS_CONFIG_FILE	The name (including path) of the config file that will be used when reconfiguring. Typically this is the one environmental variable that is set in the user's startup script for MatSeis. All other variables are set in the config file itself.
MS_BG_COLOR	A 3 element comma separated list of rgb values (ranges from 0=black to 1=full color) specifying the MatSeis background color.
MS_FG_COLOR	As above but for the foreground color.
MS_AX_COLOR	As above but for the axes and the associated labels.
MS_FONTSIZE	A single integer specifying the point size of the font used for labelling the MatSeis display.
MS_GUI_FONTSIZE	As above but for the fonts used in the various popup GUIs.

MS_GUI_FONTWEIGHT	As above, but a string specifying the fontweight. Acceptable values are: normal or bold.
MS_DISTFLAG	?
MS_W_AMP	A single float value specifing the maximum amplitude (in pixels) of the waveforms displayed in MatSeis. The default value is 20.
W_SAMPLES	This is single integer specifing the waveform time resolution. Regardless of the sample rate, at some scale, several points will end up being plotted at the same postion; this variable controls how many will be plotted and thus improves performance without affecting visual perception. The default value is 1000.
MS_TT_TYPE	A string specifying the type of travel time data read in. Allowable values are: LOCSAT, TTMATRIX, and MASTERIMAGE. The default values is LOCSAT.
MS_TT_WIDTH	A single float specifying the width in seconds of the travel time curves plotted in MatSeis.
MS_LOCSAT_DIR	An unfortunate name for a string specifying the location of the LOCSAT format travel time tables.
MS_LOCSAT_PREFIX	A string specifying the prefix for the LOCSAT travel time tables. The tables should all have the form: prefix.phase_name, e.g. iasp91.P, iasp91.PcP, etc.
MS_TTMATRIX_DIR	A string specifying the location of the TTMATRIX format travel time tables. In this case we don't need a prefix because the files are assumed to be just the phase names, e.g. P, S, etc.
MS_ARRIVAL_DEF	A string specifying the default phase name that will be used for picking arrivals. Default is UNK.
MS_DATABASE	A string specifying the type of input database. Allowable values are: LOCAL, CSS_SQL, CSS_FLATFILE
MS_DB1_DIR	A string specifying the location of the LOCAL format input database. Table names are assumed not to include a prefix (e.g origin, channel, site) so none need be specified.
MS_DB2_SQLPLUS	A string specifying the sqlplus-type command used to query the input database. e.g. sqlplus
MS_DB2_USERNAME	A string specifying the username for the input database account to be accessed.
MS_DB2_PASSWORD	A string specifying the password for the input databaase account to be accessed.
MS_DB2_DATABASE	A string specifying the name of the input databaase to be accessed.

MS_DB2_AFFILIATION, AMPLITUDE, ARRIVAL, ASSOC, EVENT, INSTRUMENT, LASTID, NETWORK, ORIGERR, ORIGIN, REMARK, SENSOR, STAMAG, SITE, SITECHAN, WFTAG, WFDISC

In each case, a string specifying the name of the corresponding CSS3.0 format table name for the input database account.

MS_DB3_DIR	A string specifying the location of the directory containing the CSS3.0 flatfile input database tables.
MS_DB3_DATABASE	A string specifying prefix used in the formation of the CSS3.0 flatfile database table names. E.g if the tables are mydata.origin, mydata.arrival, etc., this variable would be mydata

MS_DB3_AFFILIATION, AMPLITUDE, ARRIVAL, ASSOC, EVENT, INSTRUMENT, LASTID, NETWORK, ORIGERR, ORIGIN, REMARK, SENSOR, STAMAG, SITE, SITECHAN, WFTAG, WFDISC

In each case, a string specifying the name of the corresponding CSS3.0 format table name suffix for the input flatfile database.

MS_OUT_DATABASE	A string specifying the type of output database. Allowable values are: CSS_FLATFILE only at this time.
MS_OUT_DB3_DIR	A string specifying the location of the directory containing the CSS3.0 flatfile output database tables.
MS_OUT_DB3_DATABASE	A string specifying prefix used in the formation of the CSS3.0 flatfile output database table names. E.g if the tables are mydata.origin, mydata.arrival, etc., this variable would be mydata

MS_OUT_DB3_AFFILIATION, AMPLITUDE, ARRIVAL, ASSOC, EVENT, INSTRUMENT, LASTID, NETWORK, ORIGERR, ORIGIN, REMARK, SENSOR, STAMAG, SITE, SITECHAN, WFTAG, WFDISC

In each case, a string specifying the name of the corresponding CSS3.0 format table name suffix for the output flatfile database.

MS_VMSF	A string specifying the name (including path) of the Velocity Model Specification File (VMSF) used by the locator tool.
MS_SASC_DIR_PREFIX	A string specifying the location of the Slowness Amplitude Source Correction (SASC) files used by the locator tool. Location does not require the use of SASC data.
MS_LOCATOR_INIT_PAR	A string specifying the location of the parameter (par) file used by the locator tool.

MS_LOCATOR_UPDATE_DEF

	A flag (0 or 1) to control whether after each location the old origin information is updated (1) or a new origin is created (0).
MS_LOCATOR_SAVEFILE	A flag (0 or 1) to control whether or not to keep (1) or overwrite (0) the output file created by the locator tool.
MS_MAP_WATER_COLOR	A 3 element comma separated list of rgb values (ranges from 0=black to 1=full color) specifying the water color displayed in map tool.
MS_MAP_COAST_COLOR	As above, but for the color of the line used to draw the coast.
MS_MAP_LAND_COLOR	As above, but for land color.
MS_MAP_COAST_WIDTH	An integer value specifying the width of the line used to draw the coast. Default is 1.
MS_MAP_GRIDLINES	A string (on, off) to specify whether or not to draw grid lines on the map.
MS_MAP_LOCTION	A string (on, off) specifying whether or not to automatically show the lat,lon position of the cursor in the map. Default is off.
MS_MAP_GCTHEO	A string (on, off) specifying whether or not to draw great circle paths connecting the selected origin and the stations with waveforms or arrivals.
MS_MAP_GCOBS	As above, but to draw great circles using the azimuth information with arrivals and slowness coming from the travel time curves.
MS_MAP_RANGE	A string (on,off) specifying whether or not to draw small circles as 1 degrees, 5 degrees, 20 degrees, and 100 degrees from the selected origin. These are useful for defining local, regional, teleseismic ranges.
MS_MAP_COAST	A string specifying the coastline data set used for drawing coastlines. Acceptable values are: Default coastline, GSHHS crude, GSHHS low, GSHHS intermediate, GSHHS high, GSHHS full.
MS_MAP_AXES_LIMIT	Four comma separated floats specifying the min lat, max lat, min lon, max lon for the map view. If these are set in the config file, the map will automatically come up zoomed to this view.
MS_MAP_AXES_LIMIT_MAX	As above, but these limits specify the entire allowable range of the map (i.e. if you try to unzoom beyond this range you won't be able to). Default values are: -89.5, 89.5, -179.5, 179.5.
MS_MAP_PROJECTION	A string specifying the map projection. Allowable values

	are: Stereographic, Orthographic, Azimuthal Equal-area, Azimuthal Equidistant, Gnomonic, Sattelite, Albers Equal-area Conic, Lambert Conformal Conic, Mercator, Miller Cylindrical, Equidistant Cylindrical, Oblique Mercator, Transverse Mercator, Sinusoidal, Gall-Peters, Hammer-Aitoff, Mollweide
MS_MAP_STA_MARKER	A string specifying the marker used for the stations plotted on the map. Accetable values are: none, point, plus, cross, asterisk, circle, square, diamon, trangle-up, traingle-down, triangle-left, triangle-right, pentagram, hexagram.
MS_MAP_STA_COLOR	A 3 element comma separated list of rgb values (ranges from 0=black to 1=full color) specifying the station symbol color.
MS_MAP_STA_SIZE	A single decimal value specifying the point size of the station symbols.
MS_MAP_STA_FONTSIZE	A single decimal value specifying the point size of the font used to lable the stations.
MS_MAP_STA_SEL_COLOR, STA_SEL_SIZE, STA_SEL_FONTSIZE	As above, but for the selected stations (to differentiate them).
MS_MAP_ORG_MARKER, ORG_COLOR, ORG_SIZE, ORG_FONTSIZE	As above, but for origins rather than stations.
MS_MAP_ORG_SEL_COLOR, ORG_SEL_SIZE, ORG_SEL_FONTSIZE	As above, but for the selected origin (to differentiate it).
MS_MAP_DATA_DIR	A string specifying the location of the data file read in (e.g. topography).
MS_MAP_DATA_FILE	A string specifying the name of the data file to be read in (.e.g world15min.mf).
MS_MAP_GSHHS_DIR	A string specifying the location of the coast line data files.
MS_MAP_TITLE	A string specifying the title of the map.
MS_MAP_ZOOMBUTTONS	A string (on,off) specifying whether or not the zoom buttons on the map are visible. To make screen dumps the user may want to turn the buttons off.
MS_MAP_DATABUTTONS	As above, but to control the visibility of the data set buttons.
MS_MAP_BORDER	A string (on, off, fancy) to control whether or not a border is shown on the map.